# Various Optimization Techniques used in Vehicle Routing Problem: A Review

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## ABSTRACT

In mathematics, computer science and economics, optimization, refers to choosing the finest element from some set of existing alternatives. In the simplest manner, this means solving problems in which one seeks to minimize or maximize a real function by methodically choosing the values of real or integer variables from within an acceptable set. An optimization problem is the predicament of getting the *best* solution from all possible solutions. In this review paper we will discuss various optimization techniques for vehicle routing problem (VRP) which is a combinatorial optimization problem seeking to serve n customers with a group of vehicles.

## Keywords

Vehicle Routing Problem, Optimization techniques, Ant Colony Optimization, Vehicle Routing Problem with time windows, Vehicle Routing Problem with pick-up and delivery.

## I. INTRODUCTION

In mathematics and computer science, an optimization problem is the predicament of getting the best solution from all possible solutions. Officially, an optimization problem A is a quadruple (I,f,m,g)[1], where

- I is a set of instances;
- given an illustration $x \in I$, f(x) is the set of all possible solutions;
- given an illustration x and a feasible solution y of x, m(x,y) denotes the measure of y, which is usually a positive real.
- g is the objective function, and is either min or max.

The goal is then to find for some instance x an best solution, that is, a optimal solution y with

$$m(x,y) = g\{m(x,y') \mid y' \in f(x)\}.$$

Vehicle routing problem (VRP) is a combinatorial optimization problem seeking to serve n customers with a group of vehicles. It was anticipated by Dantzig and Ramser in 1959. VRP is an important problem in the fields of transportation, distribution and logistics.[2] Often the context is that of delivering commodities located at a central repository to customers who have placed orders for such goods. Inherent is the goal of minimizing the cost of distributing the goods. Many methods have been developed for searching for good solutions to the dilemma, but for all but the smallest problems, finding overall minimum for the cost function is mathematically complex.

## II. HYBRID ANT COLONY OPTIMIZATION IN VRP

In the Vehicle Routing Problem (VRP) a navy of vehicle with limited capacity has to be routed in order to visit a set of customers at a minimum Dantzig and Ramser in 1959[3]. Due to the basic cost. The problem was first introduced by interest as difficult combinatorial optimization problem and to the economical importance of applications VRP has received a lot of attention and many algorithms both exact and heuristics have been developed since then to solve general problem and real world cases. As most combinatorial optimization problems, VRP is known to be NP-hard problem.

ACO is a branch of newly developed form of artificial intelligence called swarm intelligence (SI) . ACO algorithm is inspired by social behavior of ant colonies. Although they have no sight, ants are capable of finding the shortest route between a food source and their nest by chemical materials called pheromone that they leave when moving.

ACO algorithm was firstly used for solving travelling sales man problem (TSP) [4] and then has been successfully applied to a large number of difficult problems like the quadratic assignment problem (QAP) [5],routing in telecommunication networks, graph coloring problems,scheduling, etc.

### A. Vehicle Routing Optimization Problem

The Vehicle Routing Problem (VRP) requires the determination of a optimal set of routes for a set of vehicles to serve a set of customers. The problem as it appears on real life may have several classes of additional constraints, as limit on the capacity of the vehicles, time windows for the customer to be served, limits on the time a driver can work, limits on the lengths of the routes, etc [7]. We want to define routes for the vehicles starting and ending at the distribution center that satisfy the clients demand at a minimum total cost. Meanwhile, it must meet the following conditions and assumptions:

- Every customer is visited exactly once by exactly one vehicle.
- All vehicle routes begin and end at the distribution center.
- For every vehicle route, total demand does not exceed vehicle capacity Q.
- For every vehicle route, total route length does not exceed a given bound L.

### B. Ant Colony Algorithm in the Application of Vehicle Routing Problem (VRP)

Basing on Ant Colony Algorithm, They used the vehicles to replace the ants, and let each vehicle start from the distribution center to serve each customer. When its capacity is able to meet the next customer’s requirement, the vehicle will serve him.

Otherwise, the vehicle will return to the distribution center for re-loading goods and start from the distribution center again according to the principle that total demand does not exceed its capacity to serve the remained customers. It seems when each customer has been served by the vehicle as an ant completed this traversal. Then the ant will wait for other ants to complete a traversal. When all ants have completed their traversal, the current shortest path and its length will be saved, and update the pheromone on each path, then come into the next iteration.

### C. Advantages and Disadvantages

Improved Hybrid Ant Colony Algorithm, which enhances the algorithm ability of global optimization, and avoiding stagnation and falling into a local optimization. According to the characteristics of The Vehicle Routing Problem, it proposes the Insertion Point Algorithm to further obtain feasible solution of VRP based on solution of the TSP. In addition, we have obtained a better solution and further improved the performance of Ant Colony Algorithm.

The disadvantage of the algorithm is that when we want to improve the ability of finding out the global optimization, we also wake the convergence of the global optimization. The algorithm could be improved according but not limited to following tips:

- Introduce Particle Swarm Optimization (PSO),optimize the parameters of Ant Colony Algorithm.
- Introduce Genetic Algorithm (GA), initialize the distribution of ant's pheromone trails

## III. OPTIMIZATION OF VRP WITH LOAD BALANCING AND TIME WINDOWS IN DISTRIBUTION

Vehicle route scheduling is an important activity in supply chain management. It is virtually a kind of vehicle routing problem with time windows (VRPTW). An improved model of VRPTW with load balancing was built up. It aims to achieve minimum vehicles, the shortest distribution distance, load balancing and customer's time demand. The algorithm was designed to two-stage.The first Stage was used to find the vehicle route schedule through particle swarm optimization. An improved inertial coefficient was considered to enhance the search speed. The second Stage was implemented for load

balancing. The optimal or sub-optimal solution can be found

efficiently through the proposed model for medium size vehicle routing problem.

The solving methods for VRP include exact algorithm and

heuristics. For large size problem, it won't be helpful using exact algorithm. Many kinds of heuristics were therefore proposed. In 1964, Clarke and Wright proposed savings method to solve VRP with small size [6]. In 1970s, many researchers suggested two-stage heuristics suitable for solving

larger size problems, for example, Gillett and Mille suggested

sweep algorithm which is of route first -cluster second method,

Christofides proposed cluster first - route second method [7-8].

In 1980s, Fisher and Jaikumar proposed Mathematical Programming Based Heuristics [9]. Since 1990s, some artificial intelligent methods have been suggested, such as Genetic Algorithm, Tabu Search, Simulated Annealing, Ant Colonies Optimization and Particle Swarm Optimization [6-9].

In this study, the VRP with load balancing and time windows was studied. Four aims, namely, minimum vehicles, the shortest distribution distance, load balancing for vehicle with distribution tasks and the coordination with the consignee's time of acceptance, are considered. The optimal or suboptimal solution can be found efficiently through the proposed model with two-stage algorithm for medium size vehicle routing problem.

A distribution center has M trucks of the same type and

charge for the delivery of products to C customers. It receives

orders from downstream customers every day. Then the workers begin sorting and packaging products according to these orders. Next, the products are assigned to and loaded on

the M trucks. Followed by, the trucks depart from the distribution center and deliver products to customers along some routes, finally return to distribution center. In this kind of Vehicle Route Problem, several things should be considered. The quantities of products ordered from each customer are unequal and the products from the same order should not be separated to deliver. The capacity of each truck is not allowed to exceed. To avoid the unbalance of driver's workload, the load assigned to each truck should be close to the average level as possible. In addition, for the convenience of customer, truck should finish delivery of products at given time interval. As for cost, the minimum trucks and shortest

distribution distance will be preferred.

### A. *Stage I-Partical Swarm Optimization*

Particle swarm optimization (PSO) is a promising evolution

algorithm due to its simplicity, high efficiency and robustness. In PSO, the swarm is typically modelled by particles in multi-

dimensional space that have a position and a velocity. These

particles fly through hyperspace (i.e. Rn) and have two essential reasoning capabilities: their memory of their own best position and knowledge of the global or their neighborhood's best. Members of a swarm communicate good positions to each other and adjust their own position and velocity based on these good positions.

### B. *Stage II- Load Balance*

Generally, the workload of each truck driver should be kept

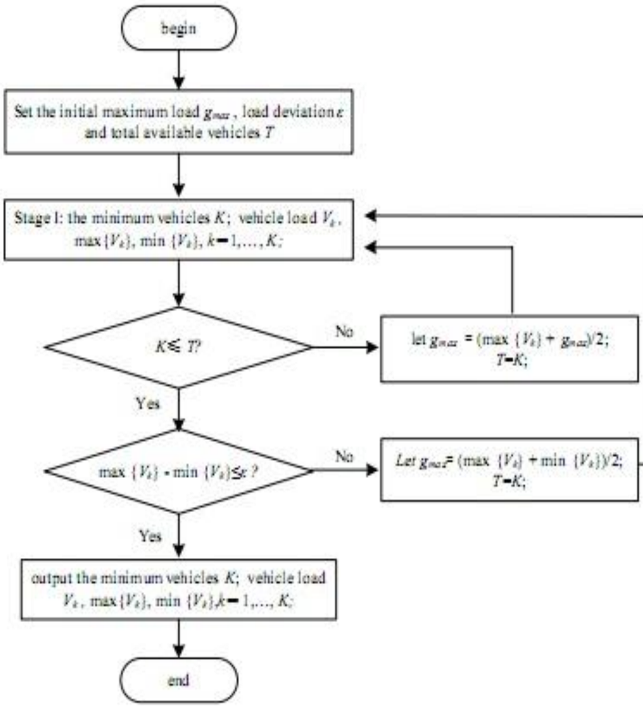
at an average level. Otherwise, it will weaken the hotness of

those truck drivers with high workload and further result in the reduction of distribution efficiency and customer satisfaction. So the load balance should be considered as possible. The demand of customer is, however, not allowed to separate in distribution practices. In this study, the maximum load and minimum load are set up to balance the truck load. It can be assumed to an approximate state of balance if the deviation between maximum load and minimum load is within an acceptable scope.

The procedure was described in Fig . The value will

affect the efficiency of the solution. The smaller it is the longer the solving time is. Sometimes, the best solution can not be found if is too small. So the decision maker can set up its value according to the reality. Two flexible methods are

suggested to determine the value of . One is to directly evaluate it by the experience of decision maker himself. If it is acceptable, then the current best solution may be accepted.The second is to adjust to an acceptable scope according to the current best solution.




PROCEDURE FOR LOAD BALANCE

### *C. Result(VRPTW)*

Effective Customer Response requires that distribution should be implemented not only with right product but also at right time.In this study an improved model of VRPTW with load balancing was built up.The customer's location and demand are sometime not known in advance.It can be viewed as akind of stochastic vehicle routing problem.

## IV. VRP WITH SIMULTANEOUS PICKUP AND DELIVERY

The vehicle routing problem with simultaneous pickup and delivery (VRPSPD) is an extension to classical vehicle routing problem (VRP) where customers require pickup and delivery service simultaneously. The objective of this problem is to determine the optimal set of routes to totally satisfy both the pickup and delivery. We propose a modified particle swarm optimization to solve this problem. The solution representation for VRPSPD with m customers is several (m+1)-dimensional particles. In the decoding process, particles will be transformed to vehicle allocation matrices with the sweep algorithm, and then the priority matrices of customers served by the same vehicle are evaluated. Based on the two matrices, the vehicle routes are constructed. The proposed algorithm is evaluated using some benchmark datasets which are publicly available, and the experimental results prove that our proposed method is effective and efficient.

The vehicle routing problem with simultaneous pickup and delivery (VRPSPD) is an extension to the vehicle routing problem (VRP), a well-known combinatorial optimization problem firstly proposed by Dantzig and Ramser[10], in which vehicles are not only required to deliver goods to customers but also to simultaneously pick up goods from customers. All delivered goods are originated from the depot and all pickup goods are transported back to the depot. The number of vehicles is usually not known in advance. The objective of VRPSPD is to minimize the total routing cost for a fleet of vehicles. Since cost is closely associated with distance, it is equal to minimize the total distance traveled by the vehicles. The VRPSPD is common in practice. In the context of distribution process, customers may have both a delivery and a pickup demand. For example, in the soft drink industry, soft drinks are delivered to the grocery stores. Empty bottles and reusable pallets/containers are returned to the factory. During the last decades, environmental awareness has resulted int olegislation, forcing companies to take responsibility for their products of whole lifecycle. Therefore, the distribution networks must be designed in a bi-directional way for the new and used products. These customers may not want to be served separately for the delivery and pickup, because a handling effort is necessary for both activities and this effort may be considerably reduced by a simultaneous operation.

Many different approaches have been developed to solve VRPSPD. Min [11] was the first one to tackle this extension problem, solving a practical problem faced by a public library.The customers were first clustered into groups and then in each group the traveling salesman problems were solved. To obtain a final optimum solution, arcs with carrying load exceeding the capacity of the vehicles were penalized. Halse[12] designed a cluster-first routing-second approach. In the first stage, the assignment of customers to vehicles was performed, and then a routing procedure based on 3-opt was applied. Dethloff [13] developed an approach based on cheapest insertions. The insertion criterion took into account

three metrics: travel distance, residual capacity, and radial surcharge. Salhi and Nagy [14,15] proposed two different methods. The former used four insertion-based heuristics for generating solution while the latter used a local search heuristic with four phases. Chen and Wu [16] proposed an insertion procedure and a hybrid metaheuristic method based on the record-to-record travel, tabu lists and route improvement routines. Tang and Galvao [17] developed a tabu search algorithm which was intensified and diversified by the use of a frequency penalization scheme. The recent article for VRPSPD was published by Hoff et al. [18], the authors developed a tabu search heuristic capable of producing lasso solutions. Although VRPSPD is a NP-hard problem, there are exact methods to solve it. Dell'Amico et al. [19] were the first

to introduce an exact method for this problem. They presented an optimization algorithm based on column generation, dynamic programming, and branch and price method. However, the computational complexity was high,so it adapted to solve the small-size problems.

Particle swarm optimization is a population based stochastic optimization technique inspired by the social behavior of bird flock (and fish school, etc.), as developed by Kennedy and Eberhart [20]. PSO can solve a variety of difficult optimization problems [21]. It uses the physical movements of the individuals in the swarm and has a flexible and well-balanced mechanism to enhance and adapt to the global and local exploration abilities. Another advantage is the simplicity in coding and consistency in performance.

### A. *Result(VRPSPD)*

It presents an enhanced particle swarm optimization for VRPSPD. The performance of the approach is evaluated for comparison with the result obtained by other methods for a number of benchmark instances. Although the global optimality cannot be guaranteed to find at all times, the performance of the results is greatly improved while the total cost is only a little larger than the optimum solution. Moreover, the proposed algorithm always uses less or equal no of vehicles. Although the proposed algorithm is efficient for solving the VRPSPD we do not know whether it is also efficient on 1-PDTSP,TSPB and other more complex combinatorial optimization problems.

## V. ACRONYMS

VRP- Vehicle Routing Problem

TSP- Travelling Salesman Problem

ACO- Ant Colony Optimization

VRPSPD - Vehicle Routing Problem with Simultaneous Pickup Delivery.

PSO-Particle Swarm Optimization

VRPTW:Vehicle Routing Problem with Time Windows

## VI. CONCLUSIONS

In this paper we have outlined the most important optimization techniques for Vehicle Routing Problem.The key points of Ant colony Optimization, Vehicle Routing Problem with Time Windows and Vehicle Routing Problem with simultaneous pick up and delivery.

Improved Hybrid Ant Colony Algorithm, which enhances the algorithm ability of global optimization, and avoiding stagnation and falling into a local optimization. The disadvantage of the algorithm is that when we want to improve the ability of finding out the global optimization, we also wake the convergence of the global optimization. In VRPTW the customer's location and demand are sometimes not known in advance. It can be views as a king of stochastic vehicle routing problem. In VRPSPD although the global optimality cannot be guaranteed to find at all times, the performance of the results is greatly improved while the total cost is only a little larger than the optimum solution. Moreover, the proposed algorithm always uses less or equal no of vehicles. Although the proposed algorithm is efficient for solving the VRPSPD we do not know whether it is also efficient on 1-PDTSP,TSPB and other more complex combinatorial optimization problems.

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