

USING BIO-INSPIRED ALGORITHMS

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Abstract:

Vehicle Routing Problem (VRP) plays an important role in logistics management and has been broadly used as a part of Transportation Framework, Logistics Distribution Framework, and Faster Delivery System. In this paper, we discuss the characteristics and classification of VRP, the constraints in VRP Solutions and future of VRP solutions in coming years. We also discuss the various VRP Solutions using bio-inspired algorithms like Ant Colony Optimization (ACO), Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO) and Genetic Algorithm (GA). VRP is viewed as a smart vehicle routing problem and the intelligent heuristic algorithm will be a critical field of future research.

Key Words: Vehicle Routing Problem, VRP, Bio-inspired algorithms, Time window Constraints, logistics management

Introduction

The Vehicle Routing Problem (VRP) is a generalization of the Traveling Salesman Problem. The goal of VRP is to find the optimal set of routes for a fleet of vehicles delivering goods or services to various locations. The VRP was first stated as Truck Dispatching problem [G. Dantzig and J. Ramser, 1959], for a fleet of gasoline delivery trucks between a bulk terminal and a number of service stations supplied by the terminal. The distance between any two locations is given and a demand for a given product is specified for the service stations. 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.

Later, the vehicle routing problem has turned into an imperative piece of logistics management and is named the general term for such a sort of problem: by various vehicles from at least one warehouse to numerous customers, how to organize the vehicle and its course to the aggregate delivery expenses can be limited. At this point, in principle, the VRP problem is characterized as arranging a progression of loading and unloading points, and additionally, the comparing the route traffic, with the goal that vehicles can be requested through them. That is, to accomplish the targets and take care of specific problems, (for example, most limited separation, least

cost, time confined) under specific limitations (products request, conveyance, conveyance time, vehicle limit imperatives, travel confinements, time requirements, and so forth).

The factors to be addressed in VRP are the vehicles, vehicles capacity, route, time window, fleet size, Source, Destination and cost from Source to the destination. Some of the factors of VRP become constraints such as Capacity constraints, ex: capacity on a railway track or load capacity of the vehicle. Time (or distance) constraints, ex: the limitations on the start and end times of each task in a critical path, in which sequence of tasks that cannot be delayed without delaying the entire routine process. Time windows: Each location must be serviced within a time window and waiting times are allowed.

Bio-inspired algorithm is a field of study that loosely knits together subfields related to the topics of connectionism, social behavior and emergence with the VRP to find an optimal solution.

Related Works

The classical Vehicle Routing Problem (VRP) focus is to find a set of routes at a minimal cost (finding the shortest path, minimizing the number of vehicles, etc)

based on the objective function, beginning and ending the route at the depot, so that the known demand of all nodes are fulfilled. Each node is visited only once, by only one vehicle, and each vehicle has a limited capacity. Some formulations also present constraints on the maximum traveling time. The vehicle routing problem with split deliveries (VRPSD) presented the mathematical formulation of the problem and analyzed the economy which allows a customer is fulfilled by more than one vehicle, economy both related to a number of vehicles and total distance traveled [Ivona Brajevic,2011]. It is also considered time windows constraints and observed that time window constraints cause the worst-case performance analysis for the vehicle routing problem with split deliveries. The authors have given an idea that the cost savings that can be realized by allowing split deliveries is at most 50%.

They also study the variant of the VRPSD in which the demand of a customer may be larger than the vehicle capacity, but where each customer has to be visited a minimum number of times.

The VRP with Time Windows (VRPTW) assumes that deliveries to a given customer must occur in a certain time interval, which varies from customer to customer. Time windows are defined as hard (or strict) when it is not allowed to deliver outside of the time interval. Soft time windows, on the other hand, allow deliveries outside the boundaries against a penalty cost [Suresh Nanda Kumar,2015].

Fig.1. Depicts the characteristics and a classification of VRP.

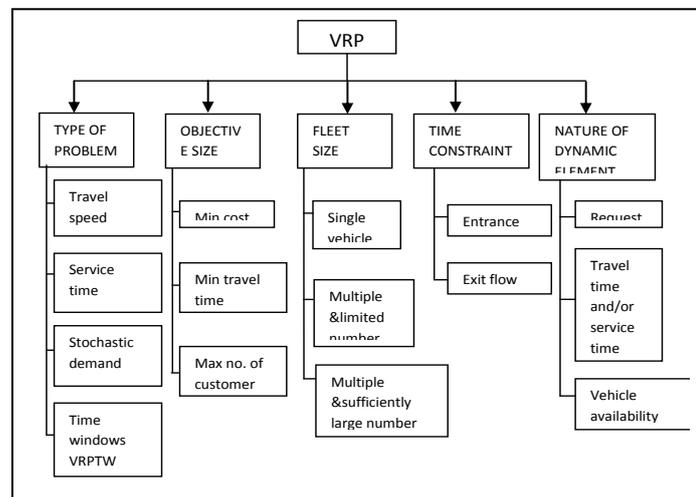


Fig.1. Characterization of VRP.

In the VRP with Pickup and Delivery (VRPPD), goods need to be picked up from a certain location and dropped off at their destination. The pick-up and drop-off must be done by the same vehicle, which is why the pick-up location and drop-off location must be included in the same route. A related problem is the VRP with backhauls (VRPPB), where a vehicle does deliveries as well as pick-ups in one route. Some customers require deliveries and others require pick-ups. The Multi Depot VRP (MDVRP) assumes that multiple depots are geographically spread among the customers. The Periodic VRP (PVRP) is used when planning is done over a certain period and deliveries to the customer can be done in different days. For the PVRP, customers can be visited more than once, though often with limited frequency.

Observation of Characteristics of VRP

1) The number of stops on the route deals with the question how many customers need to be served.

2) Load splitting occurs when a vehicle can serve the customer demand in multiple trips by, for example, serving half of the demand, going back to the depot, filling up the vehicle and serving the other half of the demand.

3) The request times of new customers define when new customers are placing their orders. In most VRPs, all the customer orders will be known in advance and no new customer requests will come in.

4) Onsite service or waiting times indicate the exact time a vehicle has to wait for a customer before it can start the service or the amount of time it takes to perform the service.

5) A time window is an interval in which the customer has to be served and can be divided into soft and strict windows, or a mix of both categories distinguishes the evolution, quality, availability, and processing of information.

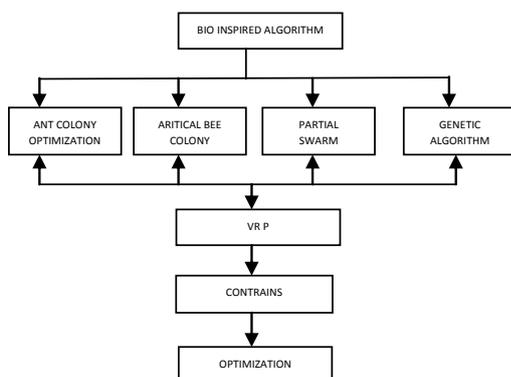
Evolution of information deals with how the input of the VRP is revealed during the routing process. The quality of information depends on the moment the decision has to be made. Information can either be known with certainty (deterministic) or can be a random variable with a known probability distribution (stochastic) [Suresh Nanda Kumar,2015]. In **Two-Echelon Vehicle Routing Problem (2E-VRP)** the goods are delivered from depots to intermediary satellites, also known as intermediate depots, and then to the customers. In the case of **Asymmetric capacitated VRP (ACVRP)**, the costs of the arcs are asymmetric i.e. indicates that the cost to travel from consumer i to consumer j is different from j to i . **Arc Routing Problem (ARP)** puts the constraint that it must find the shortest route through all the paths and return to its starting position.

Heuristic Solutions to VRP

Construction of heuristic starts from an empty solution but later filled considering feasible alternatives. The improvement heuristics inter-and intra-route are widely used into search in the solutions space of any metaheuristic [Eliana M. Toro O,2014]. Bio-inspired algorithms are capable of providing heuristic-based solutions.

Bio-inspired algorithms

Swarm Intelligence (SI)-based algorithms belong to a wider class of algorithms, called Bio-Inspired Algorithms (BIA). In fact, bio-inspired algorithms form a majority of all nature-inspired algorithms. From a theory point of view, SI-based algorithms are a subset of bio-inspired algorithms, while bio-inspired algorithms are a subset of nature-inspired algorithms [R. Yesodha, 2015]. Vehicle routing problem is one of the Nondeterministic Polynomial - Hard combinatorial optimization problem which focuses on optimizing the routes and reduces the overall cost of the routes with minimum distance [S. D. Chavan, 2015]. Bio-inspired algorithms solve optimization problems which have the capability to define and decide difficult dealings from nature by using simple rules as in Fig.2.



a) Ant Colony Optimization (ACO)

ACO is a technique useful in problems that deal with finding better paths through graphs. In [G. Dantzig and J. Ramser,1959] a mathematical model and an algorithm based on ant colony optimization to solve a long distance routing problems are considered. Small Freight size with several time constraints is solved using Last In First Out “LIFO” policy. The objective here is about reducing costs by optimizing the loading of the passenger in vehicles, grouping orders and minimizing a number of routes. The performance of the algorithm is said to be verified by using experimental data based on historical data from a large Spanish transport company. Waiting time is restricted and that penalizes the objective function within the acceptable limit. Another variant is multi-depot VRP and deals with both single and multi-depot [Beatriz Royo,2015].

b) Artificial Bee Colony (ABC)

The vehicle routing problem with time windows (VRPTW) is a well-known optimization problem and it has received a lot of consideration in the literature [Tang Italian,2016]. The VRPTW involves determining a set of routes starting and ending at a depot, wherein the demand of a set of geographically scattered customers is satisfied. Each route is traversed by a vehicle with a permanent and limited capacity, and each customer needs to be visited only once. The total demand (load) delivered in each route should not exceed the vehicle’s capacity. Time windows are imposed for the customer destinations, meaning that the vehicle is only permitted to arrive at/depart from a customer destination within a specific time window [MalekAlzaqebah,2016].

c) Partial Swarm Optimization (PSO)

PSO is an evolutionary computation technique firstly introduced by Kennedy and Eberhart [JhonJairo Santa Chávez,2015]. It is inspired by the behavior of birds when looking for their food. This algorithm is based on population. In PSO term swarm is used for a group of particles say a population which moves in search space to find the shortest distance between source and destination [IvonaBrajecic,2011]. The fitness of particles is evaluated on the basis of a search function. Particles move through search space by dynamically updating their velocities leading to the new position of the particle. This method achieves local best and global best if and only if the new values are better than previous values. After maximum iteration, this algorithm generates global best having best fitness [M. Bhuvanewari,2015].

d) Genetic Algorithm (GA)

Genetic algorithms were derived from Darwin’s theory of evolution. A genetic algorithm based hybrid approach is to solve clustered VRP. In this type of VRP passengers are grouped together to form clusters and these clusters are served by the same depot. To find

optimum clustered route for the above problem genetic algorithm is used in combination with local-global approach [M. Bhuvaneswari,2015]. This approach is used to distinguish between local and global connections of clusters. Hence genetic algorithms present a search technique which can be used to generate true or approximate solutions to optimization and search problems in a better manner. The objective for a VRP function is to the minimize the number of routes or the number of vehicles utilized; the optimal number of routes is unknown. A secondary objective is to minimize the total time or distance traveled [Sheng-HuaXu,2015].

Findings

Various vehicle routing problems and its solutions by applying bio-inspired algorithms like Ant Colony Optimization (ACO), Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO) and Genetic

Algorithm (GA) are studied in this paper. It is Guaranteed that each vehicle will leave the depot and arrive at a determine passengers It is about entrance and exit flows guarantee that each vehicle will leave a determine passenger and arrive back to the depot. It is found that the total demand of each passenger is fulfilled. Guarantee that the vehicle capacity will not be exceeded. It is known that the demand of each passenger will only be fulfilled if a determined vehicle goes by the place. It Sets a minimum time for beginning the service of passenger determine route and also generate that there will be no sub tours. Guarantee that all passengers will be served with their time. The constraints which allow finding better optimization are analyzed and shown in Table 1.

Table 1. Comparison of the different solution algorithms for VRP problem class

Ref No.	Reference	Algorithm	Travel speed	Service time	Stochastic demand	Objective function	Time windows	Independent decision variable	Category based Classification
2	Beatriz Royo 2015	ACO	Yes	No	Yes	Traveling distance; routing design	Yes	Route speed; departure time	Classic VRP
3	Tang Italian 2016	ACO	Yes	Yes	Yes	Total cost	Yes	Travel distance in each period time	MDVRP
4	MalekAlzaqebah 2016	ABC	YES	Yes	Yes	Vehicle cost, large moves	Yes	Routes; travel distance in each period; time	VRPTW
5	IvonaBrajevic 2011	ABC	Yes	No	No	Total cost	No	Route	CAPACITATED VRP
11	Sheng-HuaXu 2015	BIA	Yes	Yes	Yes	Total cost, reduce travel period time	Yes	Reduces vehicle fleet; reduce distance with the extra path.	OPEN VRP
11	Sheng-HuaXu 2015	PSO, GA	Gradual	Yes	Yes	Total cost min,	Yes	Waiting time, service time w	VRP
12	Suresh Nanda Kumar 2015	GA	AVERAGE	No	No	Total cost	Yes	Minimum route, vehicle utilized	VRPTW
13	De Jaeger 2014	VRP	Yes	No	No	Total cost	Yes	Minimize the gap between real application	GREEN VRP
14	Eliana M. Toro O (2014)	BIA	Yes	No	Yes	Quality, on-time delivery	Yes	Overall performance	VRP

Conclusions

The purpose of this review was to view the trends in composition studies related with Bio-Inspired Algorithm. It is clear that VRP problem is focused on the classification and analyzed in such a manner that testing is required to gain a better understanding. It is important to conduct more studies on the result to find the better optimization. Vehicle routing problem is mainly used in supply chain management, which plays a significant role in productivity improvement in organizations through an efficient and effective delivery of goods/services. With the BIA, I have taken a set of algorithms ACO, ABC, PSO, GA which are entitled with the VRP time windows.

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