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A Review Paper on PSO and GA Based Optimization for Vehicle Routing Problem

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Abstract*— The vehicle routing problem is basically originated from the truck dispatching problem. The VRP is used to design optimal set of routes to serve a given number of customers with a fleet of vehicles. The VRP plays an important role in the field of transportation and distribution. By following the optimal route by the fleet of vehicles total route cost can be minimized. The VRP has number of variants some of them are VRP with time window, capacitated VRP, dynamic VRP and so on. Different optimization techniques are used for resolving different kinds of vehicle routing problems. Initially exact methods were used to solve VRP but with the advancement in studies heuristic and meta- heuristic algorithms were developed for VRP optimization. Generally heuristic and meta-heuristic techniques give results which are close to optimal solution. Some of the VRP optimization algorithms are Tabu Search, Ant Colony Optimization, Particle Swarm Optimization, Genetic Algorithm, etc. In this paper main areas of concern are PSO and GA.

Keywords*—Vehicle Routing Problem; Optimization; Heuristic; Meta-Heuristic; Particle Swarm Optimization; Genetic Algorithms

I. INTRODUCTION

The Vehicle Routing Problem (VRP) is a complex optimization problem originally proposed by G.B. Dantzig and J. H. Ramser [1]. Researchers show interest in VRP because of its complexity and increasing demand in real world applications. The VRP is a class of problems dealing with the transportation of goods between one or multiple depots and customers [2]. VRP is formulated as distribution of goods with a fleet of vehicles starting from the depot and fulfilled the demands of the customers by following the shortest path and then return back to the starting point. Some of the main constraints in distribution process are; each customer must be visited once by a single vehicle, total distance travelled by the vehicles should be minimal. Some of the variants of VRP are:

A. Capacitated Vehicle Routing Problem (CVRP)

The CVRP is a classical form of the VRP. In CVRP vehicles have limited carrying capacity of the goods that must be delivered. In CVRP routes are constructed in such a way that; for every vehicle starting and end point should be same i.e. depot, all demands must be fulfilled and capacity of the vehicles should not be exceeded.

B. Open Vehicle Routing Problem (OVRP)

In case of Open VRP after fulfilling the demand of last customer of a given path, vehicles are not required to return to the depot. Researchers showed less interest towards OVRP. In OVRP one of the main issues is to minimize the number of vehicles [4].

C. VRP with Simultaneous Pickup and Delivery (VRPSPD)

In VRPSPD customers have both a delivery and pickup demand. It is also called as Pickup and Delivery Problem. In PDP goods need to be loaded from certain pickup locations and unloaded at delivery locations. The main aim is to find optimal routes for a fleet of vehicles to visit the pickup and drop-off locations so that the total cost should be minimal [5].

D. VRP with Mixed Pickup and Delivery (VRPMPD)

This problem deals with one demand and multiple solutions. In VRPMPD at a particular time customer either have pickup or delivery demand. In general, any VRPSPD solution method can be implemented to solve the VRPMPD. As mentioned in [5], VRPMPD is considered as multi-vehicle one-to-many-to-one PDP with single demand and mixed solutions.

E. Multi-Depot Vehicle Routing Problem (MDVRP)

Initially this problem was introduced by Tillman [6]. In MDVRP number of depots used serve customers is more than one. Also starting and ending depot of the vehicle should be same. Generally, the number of vehicles per depot is given as an input data.

F. Heterogeneous Fleet VRP (HFVRP)

In HFVRP, instead of using homogeneous fleet, vehicles with different capacities are used to fulfill demands of customers. As per practical point of view homogeneous fleet of vehicles is difficult to find so HFVRP has numerous applications in the industry.

Combination of above variants of VRP also exists in real time applications. To get optimum solutions (routes) for above variants of VRP different optimization techniques are used. These techniques are classified as:

Exact methods: Branch and bound, cutting plane method, branch and cut etc.

Heuristic methods: Constructive methods, two phase methods, neighbourhood search heuristics etc.

Meta-heuristics methods: Simulated annealing, PSO, GA, ACO [3] etc.

In this paper PSO and GA are main areas of concern. Different PSO and GA used for resolving variants of VRP are discussed.

The remainder of article is organized as follows: section II describes particle swarm optimization and its different modified forms. In Section III Genetic algorithm and its variants are discussed. In Last section whole paper is concluded.

II. PARTICLE SWARM OPTIMIZATION

PSO is an evolutionary computation technique firstly introduced by Kennedy and Eberhert [7]. Basically it was inspired from behaviour of birds when looking for their food. This algorithm is based on population. In PSO term swarm is used for group of particles (i.e. population) which move in search space to find shortest distance between source and destination. Each particle has its current velocity and position, local best and global best positions. Fitness of particles is evaluated on the basis of search function. Particles move through search space by dynamically updating their velocities according to equation (1). Updated velocities lead to updating position of particle through equation (2). Further evaluation updates 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.

$$v_i^{k+1} = \omega v_i^k + c_1 r_1 \left(p_i^k - x_i^k\right) + c_2 r_2 \left(p_g^k - x_i^k\right) \quad (1)$$

$$x_i^{k+1} = x_i^k + v_i^{k+1} \quad (2)$$

In above equations v_i and x_i are velocity and position vectors respectively. p_i and p_g are local and global best solutions according to the previous position of the particle. Here ω is weight factor, it tells about the dependence of current velocity of particle on its previous velocity. r_1 and r_2 are random numbers having value between [0,1]. c_1 and c_2 are acceleration coefficients having effects on global and local experience. Implementation of PSO is simple and easy to understand because of this reason it is widely used in number of applications. From last two decades PSO has gone through number of improvements and various new versions of PSO have been derived. Some of the variants of PSO for different types of VRPs are given below:

A. Average Optimal Information Based PSO

During the optimization process PSO mature evolutionary. To overcome this problem another variant of PSO can be used which is based on the average information of local optimal value and global optimal value. This type of PSO is called as average particle swarm optimization (AVGPSO) [8]. In case of AVGPSO velocity of the particles is updated by using modified equation (3).

$$v_i^{k+1} = \omega v_i^k + c_1 r_1 \left(\frac{p_i^k + p_g^k}{2} - x_i^k\right) + c_2 r_2 \left(\frac{p_i^k - p_g^k}{2} - x_i^k\right) \quad (3)$$

B. Heuristic Based PSO

Heuristic based Particle swarm optimization is designed to find optimal solutions for capacitated vehicle routing problems. To boost up the search function or to balance global and local searches, a number of linear and non linear decreasing values of ώ are used. Different strategies used to adjust inertia weight are linear decreasing (LD), nonlinear lower crescent decreasing (NLCD), nonlinear upper crescent decreasing (NUCD) and asymmetric nonlinear S- decreasing (ANSD) [9].

To improve quality of solution local search and path re-link are adopted. Local search schemes used to prevent becoming trapped in local optimal solution are swap, insertion, reverse, section swap and swap reverse. Also a heuristic algorithm namely NEH is executed for path re-link but is a time consuming process. Another algorithm called as sweep algorithm is used in combination with GRASP to produce better initial solutions.

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C. Hybrid Chaotic PSO

In classic PSO most of the swarm particles do not cover the whole search space and quickly converges towards the present local optimal solution. This is the reason behind prematurity and local optimization of PSO. To overcome the problem of Prematurity and local optimization, hybrid chaotic PSO [10] can be used. In this algorithm chaotic local search process is applied after updating the velocity and position vector of the particle through standard PSO. For further improvement in local search some strategies; like neighbour change strategy, exchange strategy, move strategy is used [10]. This algorithm can be used to solve other variants of VRP along with CVRP.

III.GENETIC ALGORITHMS

Genetic algorithms were derived from Darwin's theory of evolution. The operators used in genetic algorithm works same as that of natural selection process. In GA operators applied to current population includes reproduction, crossover, mutation and replacement. Generally set of customers is called chromosome and set of chromosomes is called population in genetic algorithms. The reproduction operator tells about the probability of dependence of next population on the solution of current population. The crossover operator, selects pairs of solutions called as parents, splits them at a random position by using crossover rate, and swaps their second parts. After the application of reproduction and crossover operator mutation operator is used, it selects an element of a solution using mutation rate and swaps with some other element. In this way new generations are created which results in better solutions. Hence genetic algorithms present a search technique which can be used to generate true or approximate solutions to optimization and search problems. A simple flow chart describing the GA process is shown in figure1.

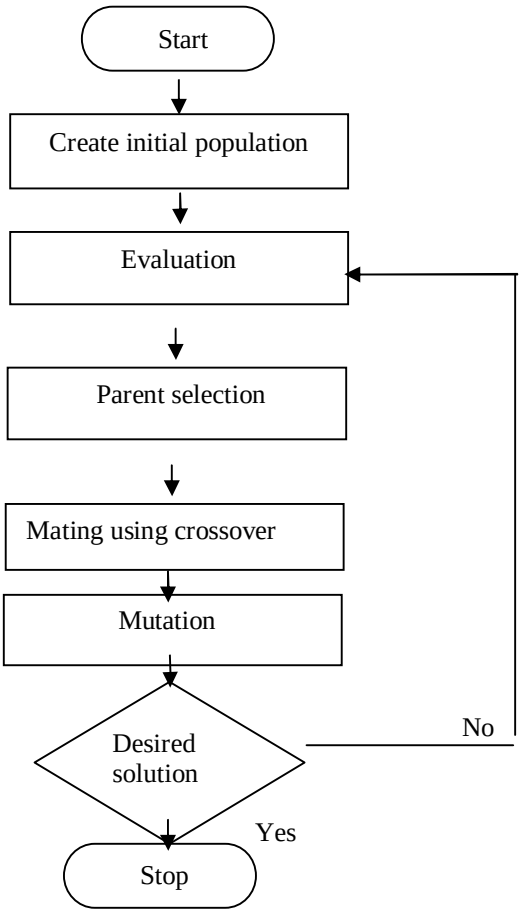

Fig.1.Simple flow chart describing the GA process

In short a standard GA can be implemented using following steps:

Initialization: Randomly generate initial population and calculate score of each individual.

Selection: Select two individuals for mating.

Crossover: Mate two selected individuals and generate offspring.
Mutation: Mutate the offspring.
Evaluation: Calculate scores of offspring.
Repeat step b-e until a pre defined number of offspring is generated.
Replacement: Insert new offspring into the population.
Repeat steps b-g until stopping condition is not satisfied (desired solution).
Genetic algorithms are widely used in large scale vehicle routing problems. In different vehicle routing problems GA with some variations is used to get optimal solutions.
Petrica Pop, Camelia Chira [11] introduces a genetic algorithm based hybrid approach to solve clustered VRP. In this type of VRP customers are grouped together to form clusters and all 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. This approach is used to distinguish between local and global connections of clusters.
Hui liu [12] represents improved GA for optimization of multi- objective model of VRP. Initial steps of the algorithm are based on the standard genetic algorithm but new improved selection and crossover operators are used. Now selection method is based on rank and standard crossover is replaced by partial mapped crossover. In this case same parents can mate number of times and new offspring retain the best gene segments, which helps to find optimal solution.

IV. CONCLUSION

Applications of transportation or distribution industries are increasing day by day. As per the need of VRP new improved optimization techniques are come into existence. Meta-heuristic techniques are widely used for optimization in various fields of VRP. Particle swarm optimization and genetic algorithms are discussed in this paper. It is found that selection PSO and updating method of GA is good. Both algorithms can be used for medium and large scale vehicle routing problems. Researchers found that standard PSO have some disadvantages so numbers of improved PSO are also adopted.

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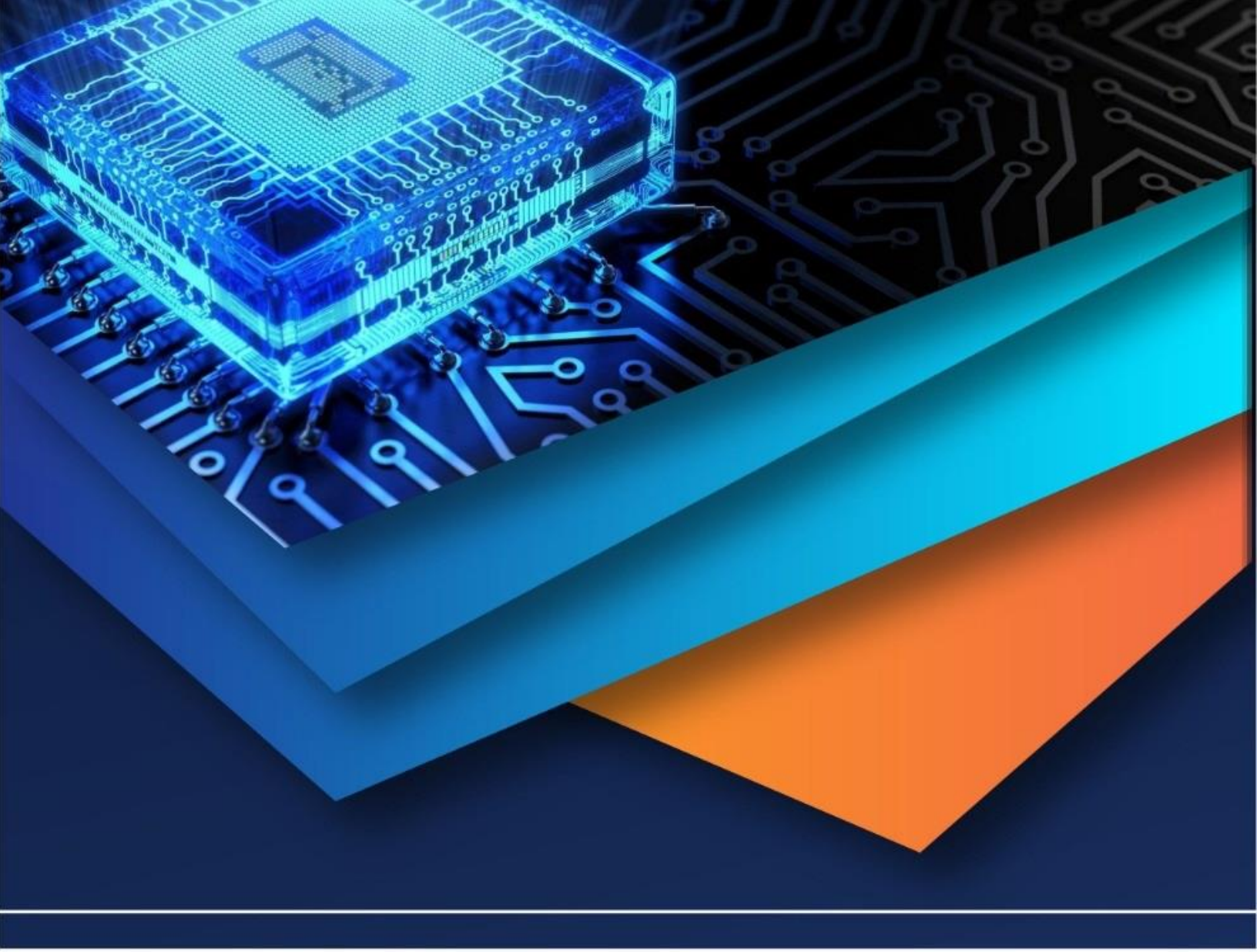

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