IEEE Sponsored 2nd International Conference on Innovations in Information Embedded and Communication Systems
ICIIECS'15

A HYBRID GENETIC ALGORITHM FOR VEHICLE ROUTING PROBLEM WITH TIME WINDOWS

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***Abstract*— The Vehicle Routing Problem with Time Windows (VRPTW) consists of a homogenous set of vehicles and a set of customer located in a city. In VRPTW all the vehicles starts from the depot visit the customer and end at the depot. Each customer is visited exactly by one vehicle within the specified time window. The objective is to minimize the number of vehicles and total distance travelled simultaneously. This represents the multiobjective Vehicle Routing Problem with Time Windows. The proposed work consists of Hybrid Genetic Search with Diversity Control using the Genetic Algorithm for solving the VRPTW. The Pareto approach is used for finding the set of optimal solutions for achieving the multiobjective. The crossover operator is used for exchanging the best routes, which have shortest distance. Two mutation operators such as relocation mutation operator and split mutation operator were used in this application. In this, it accounts penalty for an infeasible solutions with respect to time-window and duration constrains. The computations are performed using the instances which are obtained from the VRPLIB.**

***Index Terms*— Vehicle Routing Problem with Time Windows, Genetic Algorithm, Multiobjective.**

I. Introduction

The Vehicle Routing Problem is a combinatorial optimization seeking to service a number of customers with a homogeneous set of vehicles. VRP is a problem which is based on the fields of distribution, transportation and logistics. Dantzig and Ramser (1959) were the first introduced the "Truck Dispatching Problem", which characterize the service delivered by a fleet of homogeneous trucks that serves the demand for oil to a number of gas stations from the central hub with a minimum travelled distance. Five years later, Clarke and Wright (1964) made this problem to a linear optimization problem that is encountered in the domain of logistics and transport. It describes how to serve a set of customers who are geographically distributed around the central depot, using a fleet of vehicles with varying capacities is known as the "Vehicle Routing Problem" (VRP).

VRP is a NP-hard problem [6] which consists of a set of m homogenous vehicles located at a depot. It delivers a specified weight of goods to their customers located in a set of n cities. All the vehicles start from the depot for delivering goods to customers and then return to the depot. The capacity for carrying weight for each vehicle is limited and only one vehicle is allowed to visit each customer with minimum number of vehicles and minimum distance. The problem is to find a set of routes satisfying these requirements and giving minimal cost. The number of vehicles in VRP should be more than one.

Genetic Algorithm belongs to the class of Metaheuristics [10] which is used for solving Vehicle Routing Problems. In GA, the populations of individuals are maintained by crossover and mutation operators. A Hybrid Genetic Search with Diversity Control using the Genetic Algorithm for solving the VRPTW. The Vehicle Routing Problem with Time Windows (VRPTW) is the same problem that VRP, in which there is a fixed fleet of vehicles with uniform capacity must service the customer demands from the central depot at minimum cost. There is an additional restriction in VRPTW, that is, a time window is associated with each customer, defining an interval where in the customer has to be supplied.

II. Problem Statement

VRPTW is associated with routing of a set of homogenous fleet of vehicles from a central depot to a set of geologically distributed customers with the known demands and the predefined time windows. The capacity of each vehicle is limited. In VRPTW, there is an additional constraint in which the customers are visited within an allocated time.

The objective is to minimize the vehicle fleet and the sum of travel time and waiting time needed to supply all customers in their required hours. Each vehicle must starts from the depot visit the customer and come back to the depot. The capacity of all vehicles is same and should service the customer based on the capacity of vehicle whether it can service the customer demand. The customer is serviced exactly by one vehicle.

If a customer is supplied after the upper bound of its time window then that solution becomes infeasible. Each route must start and end with the depot with the time window allocated to the customer. In soft time widows, the feasibility of the solution are not affected, even when there is a late service the objective function are added by the penalized value.

The instance of Vehicle Routing Problem with Time Windows (VRPTW) consists of three routes and a single depot with solution is as shown in the Figure 1.

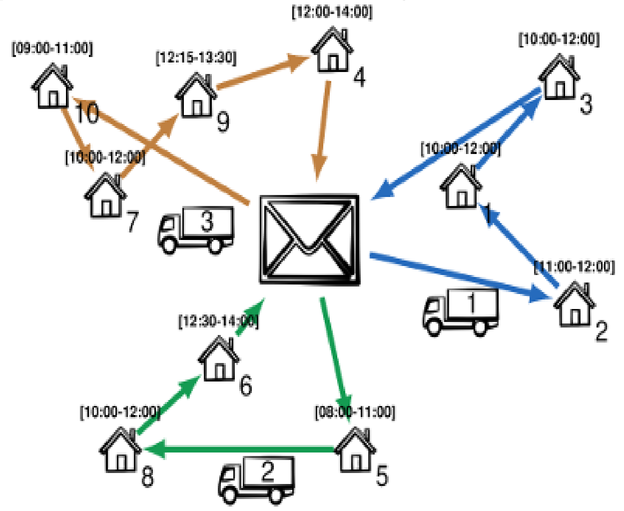

*Figure 1.*Example of a VRPTW with 3 routes and a single depot

In these problems, the service of a customer can begin within a time window $[e_i, l_i]$ defined by customer i. The vehicle cannot arrive earlier than time e_i and no later than time l_i. The regular VRP can be considered as the situation $e_i = 0$ and $l_i = \infty$ for all$1 \leq i \leq n$. When $0 < e_i < l_i < \infty$, it is also known as a double-sided time window while a single-sided time window is refer to either $e_i = 0$ or $li = \infty$, but not both. A vehicle arriving early than the earliest service time of a customer will incur waiting time. This penalizes the scheduling either in the direct waiting cost or the increase in number of vehicles.

III. Existing work

[1,7] provides a new techniques accounting a penalize for the infeasible solutions which are based on the time-window and duration constraints, which allows for evaluating the moves from any classical neighborhood based on node exchanges. This produces a method for the population diversity management which maintains the particular individual to the diversity of the population. The solutions are produced including the infeasible solution and it accounts for penalty for infeasible solution. It gives good solution quality for a large class problem.

Many researchers have presented meta-heuristics are effective approaches for VRPTW. [2] Provides a hybrid approach, which consists of Ant Colony Optimization (ACO) and Tabu search, to solve the problem. To improve the performance of ACO, a neighborhood search is introduced. Furthermore, when ACO is close to the convergence in which Tabu search is used to maintain the diversity of ACO and explore new solutions.

[3] Provides a new model for multi-objective vehicle routing problem with time windows (VRPTW). [3] Uses the goal programming. In this, the genetic algorithm uses the various heuristics that incorporates the local exploitation in the evolutionary search and the Pareto optimality concept for the multiobjective optimization. The push forward insertion heuristic and λ-interchange mechanism for the population initialization which generated randomly. The Pareto approach is used to achieve multiple objectives such as total number of vehicles and the distance is minimized.

A decomposition technique is employed to decompose the original problems to a clustering problem and a set of traveling salesman problems with time window [4]. This decomposition not only reduces the problem size but also enable the use of simpler procedures for the solution. The clustering problem is solved by using the genetic algorithm; while the traveling salesman problem was solved by using a simple heuristic. The solution of the original problem is obtained through iterative interactions between the main problem and the set of sub problems. The proposed approach is compared with the well-known insertion method and a manual scheduling of a distribution centre.

[5] It provides the Localized Optimization Framework. This framework uses two phase procedure which is an iterative process. The Optimization and De-optimization are the two phases. Optimization is carried out on the problem parts than the whole problem, and the de-optimization is taken place on the whole problem. This framework takes the domain space as Vehicle Routing Problem with Time Windows (VRPTW) and optimization methodology is genetic algorithm. Localized Genetic Algorithm (LGA) produces the improved solutions for small scale problems of VRPTW than the other heuristics.

[8] Used for solving multi-objective vehicle routing problem, this uses Genetic Algorithm (GA) for solving the problem. The real time requests are taken which are allocated randomly and it is solved based on the customer-specific time. This model satisfies the customer satisfaction. The travel distance is taken as a main objective in [9] which is solved by genetic algorithm and the set partitioning.

IV. Proposed work

This section describes the Hybrid Genetic Search with Diversity Control Algorithm for Vehicle Routing Problem with Time Windows.

1. Generate the initial population of N_p individuals. Set the generation number to t=1.
2. Generate N_p offspring. Set i=0.
3. Select two parents by 2-tournament mating selection.
4. Generate two offspring by crossover and relocation mutation.

5. Educate D (local search procedure).
6. If D infeasible then, insert D into infeasible subpopulation, Repair with probability $P_{rep.}$
7. If D feasible then, Insert D into feasible Subpopulation,
8. If subpopulation size is reached maximum then, select survivors.
9. If the best solution not enhance for It_{div} iterations, then diversify population.
10. Adjust penalty parameters for infeasibility.
11. The split mutation is performed when both the parents dominate the offspring.
12. Set i=i+2. If i=N_p then go to Step 13; otherwise go back to step 3.
13. Select the best N_p individuals from the original population and offspring. The split mutation is performed when there is any duplicate individuals are found.
14. Set t =t+1, if t=N_G then stop; orelse, go back to step 2.

In this the initial population and generation number are set. The parents are selected based on the 2-tournament selection. The offspring are generated by crossover. The feasible and infeasible solutions are in two separate subpopulations. Combine them into an offspring which undergoes a local search-based Education, if it is infeasible then it is repaired and is finally inserted into the suitable subpopulation. Each subpopulation is manages separately to trigger a survivor selection phase when a maximum size is reached, adapt infeasibility penalties, and call a diversification mechanism. If the offspring are dominated then perform a split mutation or else select the best individuals.

A. Selection

There are two selection steps in an Evolutionary Algorithm. The selection process chooses the parent for performing the crossover and the offspring are generated through mutation. A difference is that we allow the offspring that are produced by crossover and mutation to enter the population temporarily and to be candidates of parents. High-quality offspring can produce offspring immediately and improve the performance. Individuals are assigned Pareto ranks and crowding distances. The individuals that are not dominated by any other in the population are assigned rank 1 and the remaining population are assigned rank (r+1). If the individuals contain the same rank then they are evaluated by crowding distance. If an individual i is better than an individual then it must satisfy one of the two constraints (1) i should have smaller rank than j or (2) i and j have the same rank but i has a larger crowding distance.

We use a 2-tournament for the selection. In this, two individuals are selected randomly and the individual which is better is selected as a parent. We use the ($\mu + \lambda$) strategy for the environmental selection ($\mu = \lambda = N_P$). Through $N_P/2$ times of selection, crossover, and mutation, N_P offspring are generated. Among the 2.N_P individuals, we choose the better N_P individuals to continue the evolution process again, according to their ranks and crowding distances.

B. Crossover

Crossover is responsible for exchanging genetic features between selected parents. Route exchange crossover is used. The first step is to generate the offspring by copying the parents, and then, the best route is selected from each offspring. Here, the best route refers to the route that has the shortest average distance. Next, the best route from one offspring is added to the offspring. Customers who are added newly to the route will appear twice in the solution.

The newly added routes are removed from the old route because they are taken from the feasible solution. Removing of customers in the modified routes will not affect the capacity of vehicle and time window constraints**.** So, the offspring is also feasible. The crossover operator is simple, efficient, and effective. To reduce the number of vehicles, we remove the worst route and very short routes which have one or two customers.

The exchange of best route is to allow the offspring to inherit good features from the parents. Through exchanging the best route, however, some individuals in the population could have the identical best route, especially toward the end of evolution.

C. Mutation

The first operator is relocation mutation, which is based on customer relocation because it is the most basic form of all of the operators. As the evolution proceeds, the number of vehicles and the total distance are getting smaller. In this approach that the routes become better and better which makes harder to find feasible positions for relocating the customers. Thus, we aim to remove a substantial number of customers simultaneously to create more space. Then, these removed customers are reinserted one by one.

Second mutation operator is split mutation, one route is selected randomly and that route is divided into two routes. As it increases the number of vehicles, it creates the space for customer relocation. The split mutation is used to escape from the local optimum by moving to a worse solution temporarily. The split mutation is applied only when the offspring is dominated by both parents and splitting of the routes takes place at a random point.

D. Search space

The performance of heuristics is enhanced by using the exploitation for penalizing the infeasible solution. The search space of HGSDC comprises of the infeasible solutions with respect to the route constraints such as duration, load, and time windows. The fleet-size capacity is always important because the solution which contains too many vehicles may require refined cost route-reduction methods. For a late arrival to a customer, a ''time warp'' is paid to reach the edge of the time window.

Figure 2. Illustrates the assumptions on a route with five stops, with their time window and is represented by bottom to top. The horizontal axis represents the time dimension and the vertical axis represents the route. The bold line represents the possible schedule. This schedule represents the waiting time that occurs before the service to v2, and in v4 there is a late arrival which triggers a time warp. Time warp represents the waiting times, although waiting times are not penalized.

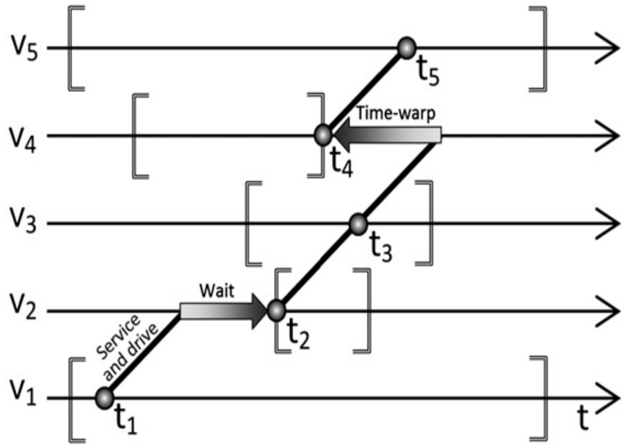

Figure 2.Waiting times and time wraps

V. CONCLUSION

A new Hybrid Genetic Search with Diversity Control is proposed for GA to solve VRPTW. It provides the efficient solution for a large class of VRPTW. The proposed work minimizes the number of vehicles and total distance simultaneously in which multiple objectives are achieved. Pareto approach is the multiobjective approach which is used for finding the set of optimal solutions. HGSDC produces the solution by allowing the participation of infeasible solution by accounting the penalty. It provides the good solution quality for large scale problem and produces the new best known solution using benchmark dataset.

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