Genetic Algorithm based on Elitism for Time Variant Vehicle Routing Problem

Virat Rehani[1], Ajit Singh[2]
[1](Assistant Professor,CTIMIT, Maqsudan, Jalandhar, India)
[2](Assistant Professor,CTIMIT, Maqsudan, Jalandhar, India)

Abstract: Vehicle Routing Problem (VRP) is considered to be an optimization problem in operational research in which the known demands of the customers are meet by a central depot. The problem aims to reduce total route cost while satisfying the constraint of capacity. Vehicle Routing Problem with Time Windows is an important variant of VRP. In this every customer is to be served within its specified time windows satisfying its capacity constraint. This is an NP-hard problem, therefore lot of meta-heuristic approaches have been proposed to infer the optimal solution. In this paper Elitism based Genetic algorithm (EGA) has been used to solve the problem. An attempt has been made to improve already existing GA. The proposed algorithm (EGA) uses new representation scheme and elitism mechanism to solve the problem. The proposed approach is validated on standard Solomon's benchmark problems and computational results shows that the proposed approach is effective and efficient.

Keywords: Vehicle routing problem, Time Windows, Genetic algorithm, Elitism.

I. INTRODUCTION

The Vehicle Routing Problem (VRP) is a complex combinatorial optimization problem that aims to provide services to a number of customers with a given number of vehicles. The problem was first introduced by Dantzig and Ramser [1] in 1959. VRP arises in the fields of transportation, distribution and logistics. It has attracted considerable attention in recent years due to its rich applications in problems that involves routing and scheduling in constraint environment like transport of goods, persons, bank deliveries, solid waste management and many more. The objective of the VRP is to deliver a set of customers with known demands on minimum-cost vehicle routes originating and terminating at depot. Till now many variants of VRP are proposed. VRPTW is one of them. In VRPTW, a set of K homogeneous vehicles having fixed capacity Q_i are required to serve N geographically scattered customers having fixed demand qi in such a way that all customers are served within their time windows $[e_i, l_i]$. A vehicle may arrive before opening time e_i but in that case it has to wait. No services can be made after closing time l_i. The objective of VRPTW is to minimize the number of vehicle used and to minimize the total travel distance such that all customers are served once and only once, all routes originates and terminates at depot while preserving the capacity and time window constraint.

As VRPTW is NP hard problem, many methods are proposed for solving it. There are mainly two categories: Exact and meta -heuristics. Exact methods are used for providing solution to small instances of VRPTW. Significant improvements in Solomon's benchmark problem instances were established by Kohl et al. [2], Larsen[3] and Chabrier [4] using exact methods. However their performance degrades when numbers of customers are increased. For solving large size problems meta heuristics are used. These methods provide optimal solution within a time bound. Survey of solving VRPTW using heuristics and meta-heuristics approaches has been presented in [5, 6, 7, 8].

In [9] [10] and [11] Taillard et al.; Chiang and Russell and Cordeauet al. repectively proposed a tabu search based solution for VRPTW. Gambardella et al. [12] proposed an ant colony optimization approach for solving the problem while [13] Shaw presents a large neighborhood search for finding the solution. Many hybridized meta heuristics [14, 15, 16] were also proposed for solving the problem. The GA approach was introduced in 1975 by Holland. GA is an effective stochastic approach that is based on the principal of survival of fittest genes that compete each other for resources. Moreover it is an effective technique that produces efficient results for NP hard problems like VRP. The first application of hybrid GA to VRPTW was given by Blanton and Wainwright. They hybridized it with greedy technique. Many hybridized algorithms have been presented for solving the problem by many researchers [17, 18].

In [19] Gehring and Homberger presented a parallelization of a two phase meta heuristic for solving VRPTW. In previous approaches [17, 19] best solution is lost. In this paper a new representation scheme for GA and a new approach for preserving the best solution have been presented.

This work is concerned with the development of a GA for a Vehicle Routing Problem. The structure of the constraints is used as the basis for a co-evolutionary strategy using co-operating populations. Problem specific knowledge is also used to define a system of pros and cons, and complementary mutation logic. Empirical results based on iterations of Solomon's benchmark data show how these features are able to improve an unsuccessful canonical GA to the point where it is able to provide a practical solution to the problem.

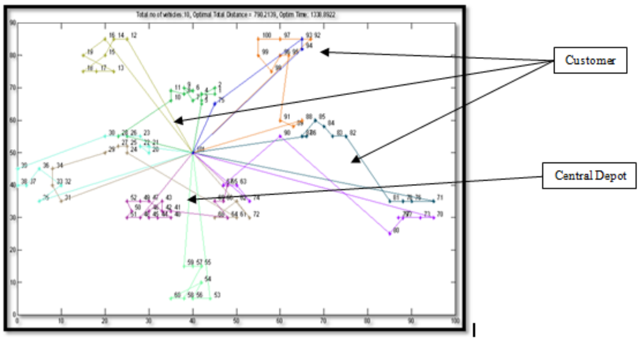

Fig.1 Vehicle Routing Problem with Time Windows

This work is concerned with the development of a GA for a Vehicle Routing Problem. The structure of the constraints is used as the basis for a co-evolutionary strategy using co-operating populations. Problem specific knowledge is also used to define a system of pros and cons, and complementary mutation logic. Empirical results based on iterations of Solomon's benchmark data show how these features are able to improve an unsuccessful canonical GA to the point where it is able to provide a practical solution to the problem.

Crux of Genetic Algorithm:

1. Condition:
   - ➔ Terminating Condition.
2. Functions:
   - ➔ Encoding/decoding and evaluation.
3. Operations:
   - ➔ Selection, Cross Over and Mutation.

Genetic Operations:

- Selection: survival strategy
- Crossover: generating new solutions by recombination of two or more parents – For intensification!
- Mutation: generating anew solutions with one parent – For diversification!

II. ELITISM BASED GENETIC ALGORITHM (EGA)

Among various heuristics and meta heuristics approaches proposed for solving VRPTW, GA has been widely used. There are three main GA operators: Selection, Crossover and Mutation. GA is an adaptive heuristic which roots its ideas from process of natural selection and genetics. Selection operators derives the GA towards the better solution, crossover operators are used for deriving new population for next generation and finally mutation operators are used to escape from local optima. However previous researches on VRPTW with GA [17, 19] lose best solutions during crossover and mutation. Often the proposed solution will rediscover these lost improvements in further iterations but there is no guarantee.

To overcome this problem, this paper uses elitism based GA (EGA). This approach preserves the fittest candidate for next generation and replaces the worst candidates of new population by best candidates preserved.

III. EXISTING SYSTEM PROBLEM

The vehicle routing problem with time windows (VRPTW) is a well known combinatorial optimization problem often met in many fields of industrial applications. One of the model designed by Boudali, I., Fki, W. and Ghedira, K. showed their interest in a coalition based multi-agent model (Coal-VRP) for the VRPTW. However, this model presents some drawbacks due to its spatial and temporal complexity [21]. There are all the operational complexities of time constraints, vehicle constraints, driver rules, customer requirements etc., but according to MJ2 on top of that the actual size of the problem to be solved is much larger than it is considered.

Even after the well-known solution provided by: T. Barth´el´emy, A. Rossi, M. Sevaux and K. S¨orensen, there were still a few question mark laid down by themselves on their work, whether:How to cluster the customers?

- How to combine efficiently high- and low-level routing?
- Which kind of meta-heuristics is most appropriate (EA, VNS)?

- Do we need special moves for clustering constraints?
- Can we combine exact and approximate methods for better solutions?
- At which level? [22].

Optimization-based methods for the Time-Dependent Vehicle Routing Problem with Time Windows (TD VRPTW) cannot solve large-scale instances because of the slow increase of the lower-bound solution, as the branching tree grows larger. Exploration of different congestion times, dissimilar speed travel ratios, and a real-life case study problem are still at large. Current technologies face serious challenges regarding modelling flexibility and optimization performance for many application types. In particular, optimization performance seems to degrade ungracefully for current routing technology when the number of orders increases above a few hundred.

Savings Algorithm of Clarke and Wright is one of the best approaches to solve the Vehicle Routing Problem, yet there is no guarantee that the solution provided by this algorithm will be anywhere close to the optimum. While experience has shown that the algorithm performs quite well most of the time, it is possible to devise "pathological" cases for which the Savings Algorithm solutions are very poor indeed. However, it is often possible to improve considerably, by inspection, a set of VRP tours produced by the savings algorithm.

Moreover the vast amount of research is focusing on the theoretical background and solution methodologies for the VRP. Most published papers are focusing on the solution methodologies comparing their results either with a benchmark problem or with others' work that solved same problem variant(s). Nonetheless, some of the shortcomings were noticed in the VRP literature [23].

Olatz Arbelaitz, Clemente Rodriguez and Ion Zamakola in an attempt to yield Low Cost Parallel Solutions for the VRPTW Optimization Problem developed a system that consists of two optimization phases: a global one, a the local one, both based on Simulated Annealing and parallelizable [24]. Still the system has been able to reach the optimal solution published for the Solomon's benchmark in an 85% of the problems only with the averages of any set of random executions are up to 5% worse than the best published.

Stefan Ropke, in his doctoral research work, Heuristic and exact algorithms for vehicle routing problems [25], did not performed any polyhedral analysis, rather worked on computational experiments. Moreover this work is typically concerned to Pick-Up and Delivery Problem with Time Windows (PDPTW).

IV. SOLUTION

1. Vehicle capacity
2. Vehicle average speed
3. Depot location
4. Number of nodes
5. Customer's location
6. Demand of every customer
7. Ready time of customer
8. Ready time of depot
9. Demand of each customer
10. Due time of each customer
11. Due time of depot
12. Service time

The Data set, accepted as benchmark and referred to as Solomon's data set, which was used in our work depicted the following details:

1. Customer number.
2. Position of depot on X coordinate
3. Position of depot on Y coordinate
4. Position of each customer on X coordinate
5. Position of each customer on Y coordinate
6. Demand time
7. Average vehicle speed
8. Ready time
9. Due date
10. Service time
11. Vehicle capacity

Using the above mentioned data set and extracting the above mentioned inputs from it, we derived the following fields in Output:

1. Route
2. Total distance
3. Iterations
4. Optimal total distance
5. Optimum route
6. Minimum distance
7. Total No. of vehicles
8. Vehicle to customers
9. Arrival
10. Customer location
11. Best solution history

V. COMPUTATIONAL RESULTS

In this section we summarize the results obtained by using EGA for solving VRPTW. The proposed algorithm is coded in MATLAB and implemented on a core i3 processor. The EGA has been tested on all the instances of Solomon benchmark problem sets involving 100 customers. The problems vary in available fleet size, vehicle capacity, traveling time of vehicles, spatial and temporal distribution of customers to be served. In classes R1 and R2 customers are randomly scattered, while the customers are clustered in C1 and C2 datasets. RC1 and RC2 are combination of R and C datasets. Each customer i has a time window [ei, li], representing the earliest as well as the latest service time at ith customer. Each instance is executed ten times and obtained results are compared with best known results and OCGA [17]. Following simulation parameters have been used: Population Size = 100; Generation size = 1000; Crossover rate = 0.75; Mutation rate = 0.25.

Table 1 presents the summary of results obtained by using EGA. Here in first column results available in literature are shown. Second column of the table presents result obtained using OCGA and third column presents result obtained using EGA. Here NV and TD denote the number of vehicles used and total distance traveled respectively.

Table 1 Comparison of EGA, Best Known and OCGA for 100 customers

S.No.	Problem	Best Known [20]		OCGA [17]		EGA	
		NV	TD	NV	TD	NV	TD
1	C101	10	827.3	10	828.4	10	828.2
2	C102	10	827.0	10	828.94	10	827.39
3	C201	3	589.1	3	591.6	3	590.3
4	C202	3	589.1	3	591.5	3	591.5
5	R101	20	1637.7	19	1650.8	20	1642.8
6	R102	18	1466.6	17	1486.1	17	1486.6
7	R201	8	1443.2	4	1252.4	8	1447.4
8	R202	4	1088	6	1079.3	4	1191.7
9	RC101	15	1619.8	14	1697.0	15	1619.2
10	RC102	14	1457.4	14	1496.2	10	2221.2
11	RC201	9	1261.8	7	1406.9	9	1266.6
12	RC202	8	1092.3	7	1176.5	8	1146.3

The proposed algorithm produced improved results in clustered problem with both small and large time windows whereas in case of mixed problem there is a tradeoff between NV and TD. If TD increases the NV decreases and vice versa. On the other hand comparable results are obtained for random problem.

VI. CONCLUSION

This paper proposes elitism based genetic algorithm for solving VRPTW. A new representation scheme of individual and three mutation operators have been proposed. The proposed algorithm has been tested on a number of benchmark problems available in literature and compared with OCGA as well as other available best solutions. Finally the computational results demonstrated that the presented approach is competitive with other available complex meta heuristics in terms of the quality of obtained solution. In future work, it may be interesting to enhance EGA with other variants of VRPTW such as rich VRP and/or stochastic VRP etc.

REFERENCES

[1] Dantzig, George B., and John H. Ramser. "The truck dispatching problem."*Management science* 6.1 (1959): 80-91.

[2] Larsen, Jesper. *Parallelization of the vehicle routing problem with time windows*. Diss. Technical University of DenmarkDanmarks Tekniske Universitet, Department of Informatics and Mathematical ModelingInstitut for Informatik og Matematisk Modellering, 1999.

[3] Chabrier, Alain. "Vehicle routing problem with elementary shortest path based column generation." *Computers & Operations Research* 33.10 (2006): 2972-2990.

[4] Bräysy, Olli, and Michel Gendreau. "Vehicle routing problem with time windows, Part II: Metaheuristics." *Transportation science* 39.1 (2005): 119-139.

[5] Kumar, Suresh Nanda, and Ramasamy Panneerselvam. "A survey on the vehicle routing problem and its variants." *Intelligent Information Management*4.3 (2012): 66.

[6] Sandhya, Vijay Kumar. "Issues in Solving Vehicle Routing Problem with Time Window and its Variants using Meta heuristics-A Survey." *International Journal of Engineering and Technology* 3.6 (2013): 668-672.

[7] Katiyar, V. "Relative Performance of Certain Meta Heuristics on Vehicle Routing Problem with Time Windows." *International Journal of Information Technology and Computer Science (IJITCS)* 7.12 (2015): 40.

[8] Taillard, Éric, et al. "A tabu search heuristic for the vehicle routing problem with soft time windows." *Transportation science* 31.2 (1997): 170-186.

[9] Chiang, Wen-Chyuan, and Robert A. Russell. "A reactive tabu search metaheuristic for the vehicle routing problem with time windows." *INFORMS Journal on computing* 9.4 (1997): 417-430.

[10] Cordeau, Jean-François, Gilbert Laporte, and Anne Mercier. "A unified tabu search heuristic for vehicle routing problems with time windows." *Journal of the Operational research society* 52.8 (2001): 928-936.

[11] Gambardella, Luca Maria, Éric Taillard, and Giovanni Agazzi. "MACS-VRPTW: A multiple ant colony system for vehicle routing problems with time windows." (1999).

[12] Shaw, Paul. "Using constraint programming and local search methods to solve vehicle routing problems." International Conference on Principles and Practice of Constraint Programming. Springer Berlin Heidelberg, 1998.

[13] Marinakis, Yannis, and Magdalene Marinaki. "A hybrid genetic–Particle Swarm Optimization Algorithm for the vehicle routing problem." Expert Systems with Applications 37.2 (2010): 1446-1455.

[14] Lau, Henry CW, et al. "Application of genetic algorithms to solve the multidepot vehicle routing problem." IEEE Transactions on Automation Science and Engineering 7.2 (2010): 383-392.

[15] Lee, Chou-Yuan, et al. "An enhanced ant colony optimization (EACO) applied to capacitated vehicle routing problem." Applied Intelligence 32.1 (2010): 88-95.

[16] Nazif, Habibeh, and Lai Soon Lee. "Optimized crossover genetic algorithm for vehicle routing problem with time windows." American journal of applied sciences 7.1 (2010): 95.

[17] Derbel, Houda, et al. "Genetic algorithm with iterated local search for solving a location-routing problem." Expert Systems with Applications 39.3 (2012): 2865-2871.

[18] Homberger, Jörg, and Hermann Gehring. "A two-phase hybrid metaheuristic for the vehicle routing problem with time windows." European Journal of Operational Research 162.1 (2005): 220-238.

[19] https://www.sintef.no/projectweb/top/vrptw/solomon-benchmark/100-customers/. Boudali, I., Fki, W. and Ghedira, K. How to deal with the VRPTW by using multi-agent coalitions.2004.http://ieeexplore. ieee.org/xpl/login.jsp? tp=&arnumber=1410039 &url=http%3A%2F%2 Fieeexplore.ieee.org%2Fxpls %2Fabs_all.jsp%3Farnumber%3D1410039

[20] T. Barth´el´emy A. Rossi M. Sevaux K. S¨orensen, 2010, Metaheuristics for Clustered Vehicle Routing Problems http://homepage.univie.ac.at /thibaut.barthelemy/eume2010-slides.pdf

[21] A. Abdelhalim, a. B. Eltawil, 2013, recent heuristics and algorithms for solving the vehicle routing problems. http://www.academia.edu/4760868/RECENT_HEURISTICS_AND_ALGORITHMS_FOR_SOLVING_THE_VEHICLE_ROUTING_PROBLEMS

[22] A. Abdelhalim, a. B. Eltawil, 2013, recent heuristics and algorithms for solving the vehicle routing problems. *http://www.academia.edu/4760868/RECENT_HEURISTICS_AND_ALGORITHMS_FOR_SOLVING_THE_VEHICLE_ROUTING_PROBLEMS*

[23] Stefan Ropke, 2005, Heuristic and exact algorithms for vehicle routing problems. A Ph.D. Thesis.