Cumhuriyet Üniversitesi Fen Fakültesi
Fen Bilimleri Dergisi (CFD), Cilt:36, No: 4 Ozel Sayı (2015)
ISSN: 1300-1949

Cumhuriyet University Faculty of Science
Science Journal (CSJ), Vol. 36, No: 4 Special Issue (2015)
ISSN: 1300-1949

The Solution of Routing Problem of Vehicle with Capacity Aiming to Minimize Costs and Increase the Level of Satisfaction with the Use of Genetic Algorithms

Farsad ATAİİ, Sayyed Mahdi SADAT KHORASGANİ, Behrooz Abbasi and Mahdi GHAFFARİ

Department of Industrial Engineering, Naragh Branch, Islamic Azad University, Naragh, Iran (IRAN)

Received: 22.03.2015; Accepted: 29.05.2015

Abstract. Vehicle routing problems are one of the best-known problems in the field of optimization. This is due to the enormous variability in the category of NP-COMPLETE. In this paper, a new hypothesis closer to this problem is presented in real terms and most of them having specific and limited capacity for the vehicle. In order to solve this problem in a short time and with high quality, the genetic algorithm is used. The results show that the genetic algorithm can be so large that it took reasonable and provide accurate solutions with minimal error.

Keywords: Vehicle routing, genetic algorithms, exact solution, meta-heuristic solution

1. INTODUCTION

Since the distribution of goods on average about 20% of the total cost of the production, improve efficiency in the transportation of goods and will save a lot of cost and competitiveness of the regional economy. Most issues in the field of distribution Vehicle Routing Problem (VRP) are considered which a generalization of the traveling salesman problem and one of the main problems of combinatorial optimization problems is heuristic methods for solving large that it was created economically efficient routing of vehicles in both the private sector and the public sector that is very important. Vehicle routing problem is defined as an area of extensive research [1] found that each and every customer's request only once, and is assumed to be fully served all vehicles are homogeneous and begin and end with a specific storage the main objective of minimizing the total distance traveled by all vehicles is to include all [2]Due to restrictions in the real world constraints are added to the classic model. A review of the literature including fleet composition and routing issues in road and maritime transport in 2010 is presented by Hoff et al. In this study a total of 120 articles which combines fleet and routing are determined by a mathematical model for this class of problems studied and presented [3]Parcha Sun et al in 2014, a review of literature in the areas of fleet size and routing of vehicles, fleet Vehicle Routing with dissimilar and developments in these issues and new studies in this area have been investigated [4].In this study, in order to bring the vehicle routing problem in real terms, and re-modeling assumptions have been added to this issue. The assumptions used in considering the limited capacity for vehicles raises complex issues. Assuming the possibility use or not to use of a vehicle is considered. There is also the possibility to meet the demand for this purpose is defined as the objective function for this problem. The objective function is to minimize unmet demand. In fact, this model is looking to employ a minimum number of items and to meet maximum of customer's demand [5].

* Corresponding author. Farsad ATAİİ

Special Issue: Technological Advances of Engineering Sciences

Meta-heuristic genetic algorithm

In recent years, the word meta-heuristic to all modern algorithms and high-level notes such as genetic algorithms (GA), gradual freezing algorithm (SA), tabu search (TS), ant colony optimization algorithms (ACO), particle swarm optimization (PSO), bees algorithm (BA), Firefly Algorithm (FA) algorithm and harmony search (HS) is used (Haghani, 1996). The main concept of meta-heuristic algorithms is:

Diversity

Convergence

In fact, the efficiency of an algorithm is measured by the above-mentioned components. "Variation or diversity" algorithm has ability to search the entire space effectively coordinated, so that almost no area of the search space is left unchecked algorithm. The strength of the algorithm in all the areas of the search space is more diverse than algorithm [6] However, this algorithm for other algorithms is in conflict with the concept of "resonance". Intensification of the algorithm's ability to focus on the areas of the search space, which is the optimal value function in those areas. It should be noted that the algorithm is a powerful algorithm to achieve the best combination of these two components [7] "Diversity" appeared often in combination with additional random or non-random loss of the compounds, in an effort to streamline the search space is explored, while the "Convergence" solutions by exploring the past and also to search for the best solution is to choose a better answer. Every successful meta-heuristic algorithm requires an appropriate balance between these two seemingly contradictory elements. If the components of the “convergence” are much stronger than usual, only a small fraction of the solution space is visible, and increases the probability of error. In this case, most of gradient-based techniques such as Newton's method are used. If a component of "diversity" is too strong, the convergence of the algorithm is done slowly and is more difficult to achieve the optimum solution; in addition, some solutions may fall from the pen. Normally, most of the solutions to randomly start and gradually reducing component "diversity" "convergence" component is on the rise, however, this process is performed simultaneously [7] The study of genetic algorithms to solve the vehicle routing model is used.

2. DESCRIPTION OF THE MODEL

As noted above, it is considered that more of the following: minimizing the total freight carried, maximizing the satisfaction of the demand of supply and demand for different products or at least not meets the demand.
In order to become both target in a single target they multiply with specific coefficient at a given target function.
Assumptions:
Assumptions used in the model are as follows:
• There is number of nodes with the demand, the demand from a storage unit can be answered.
• There are several vehicles with limited weight capacities.
• There are unlimited suppliers.
• demand nodes before the plan is clear and unchanged
• Depot vehicle began to move, and the node is rejected then returns to the depot.
• A product is considered to have the same value and volume have them all together.
Indices, parameters and variables used in the model are as follows:

Index:	
i	Set of nodes
j	Set of nodes
f	Set of nodes
k	Collection vehicles

Parameters:	
Cap^k	Vehicle capacity k
d_i	Demand node
c_{ij}	Node distance from node j
γ_2 - γ_1	Coefficients for synchronization
pen	purposes and their importance -
BigM	Unmet demand for fine unit

Variables:	
x_{ij}^k	Variable zero and one, if the route by vehicle k ij in (1) and otherwise (0)
α_i^k	Percent of demand node i k fulfilled by vehicle
D_i	Accumulated unmet demand node i
y_k	Variable zero and one. If you've used a k equal to 1, otherwise it is zero
u_i^k	Variable, the node i by vehicle k

$min \quad Z= \quad \gamma_1 \sum_i \sum_j \sum_k c_{ij} x_{ij}^k + \gamma_2 \sum_i D_i$
$s.t. \qquad \sum_i x_{ij}^k \le y_k \qquad \forall j = 2,...,N, k$
$\sum_i x_{if}^k - \sum_j x_{fj}^k = 0 \qquad \forall f, k$
$\sum_j x_{1j}^k = y_k \qquad \forall k$
$u_i^k + 1 \le u_j^k + bigM(1 - x_{ij}^k) \qquad \forall i \ne 1, j \ne 1, k$
$u_1^k = 0 \qquad \forall k$
$\sum_k x_{ii}^k = 0 \qquad \forall i$
$\sum_{i>1} \alpha_i^k d_i \le Cap^k \qquad \forall k$
$\alpha_i^k \le \sum_j x_{ij}^k \qquad \forall i \ne 1, k$
$\alpha_i^k \le y_k \qquad \forall i \ne 1, k$
$D_i = (d_i - \sum_k \alpha_i^k d_i) \qquad \forall i \ne 1$
$x_{ij}^k \in \{0,1\} \qquad \forall i, j, k$
$u_i^k, D_i, \alpha_i^k \ge 0 \qquad \forall i, k$

The objectives were as follows: (Equation 1)

• Minimizing transmission costs
• Maximizing the estimated demand
Constraints 2 show that if the device can be used to specify the path between two points on the star.
Constraints 3 assure that each node is limited to entering we must get out of it.
Every vehicle used must be removed from the depot, limit 4 it will be shown (we assume, is the depot node 1). Constraints 5, 6 and 7 to remove the restrictions on the net are created.
Constraints 8, vehicles capacity constraints if the vehicle passes the corresponding node can only be content. Constraints 10 shows that the restrictions apply to vehicles used to provide. 11 limits the amount of accumulated cumulative demand specifies. Constraints 12 Zero and a variable x indicate the constraints of 13 indicate that the variables are non-negative.

3. SENSITIVITY ANALYSIS OF THE MODEL

Writing in the GAMS model and compare the results of different (model parameters have changed as desired) have reached the following conclusions:
* If they raise the capacity of the vehicle or α (satisfaction rate) nodes increased steadily.
* Nodes with close range most of the time fall on a tour.
* If the number of vehicles is large and increasing number of tours of all uses

Number of Vehicles	**1**	**2**	**3**	**4**	**5**
Objective function value	367	1215	2042	2954	1828

* With the increasing number of vehicles with fixed capacity as the objective function's changes.

* To increase the capacity of the vehicles, the total rate of satisfaction nodes initially increases exponentially. (Linear approximation is also indicated in Figure 1.

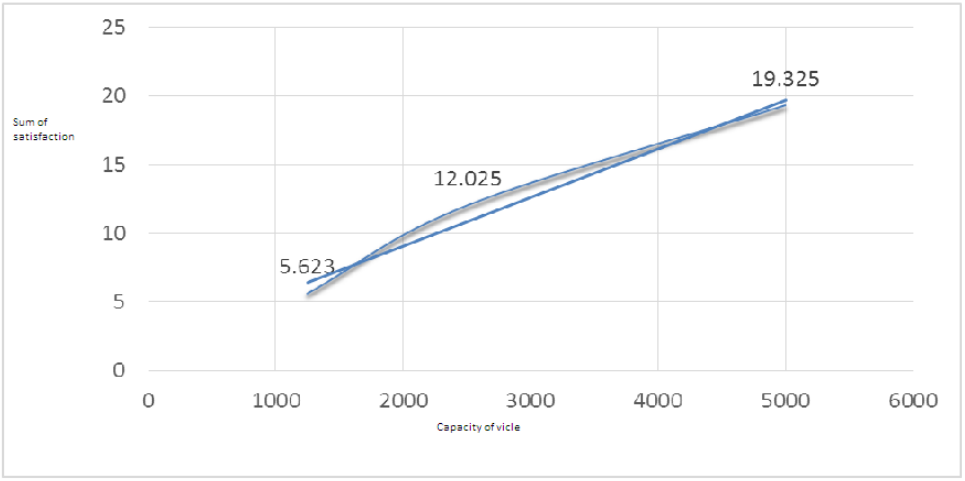

Figure 1. Linear approximation.

* With increased demand and maintain the capacity of the vehicles overall satisfaction rate of knots greatly reduced (figure 2)

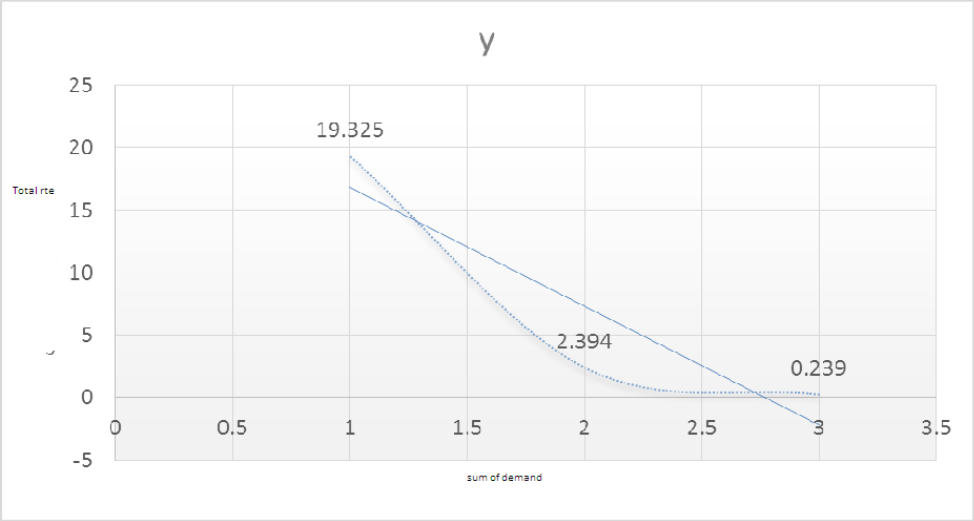

Figure 2. Satisfaction rate of knots greatly reduced.

4. THE MODEL IS SOLVED BY GENETIC ALGORITHM

Genetic algorithm is a very broad scope and growing every day with the advancement of science and technology, this method is extended to optimize and solve problems. Genetic algorithm is a subset of evolutionary computation directly related to the topic of artificial intelligence and the genetic algorithm is a subset of artificial intelligence. Genetic algorithms can be called a global search method that mimics the natural laws of biological evolution. A genetic algorithm on a set of solutions of the problem in the hope of obtaining better solutions applies the law of survival. In every generation to aid the selection process is proportional to the value answers and reproduction of selected solutions help operators that are imitations of natural genetics, better approximation of the final solution is obtained. This process causes the new generation is compatible with the conditions.

Answer defined string (chromosome): In this case there is any number of vehicles over a certain route and the route has a number of goods carried and various locations to meet the demand. Defined fields for each vehicle are defined. It has two parts, the first part of the transmission by any means, respectively, characterized and the percentage of demand in the goods is delivered to each of the points is determined.
Below an example of this field is shown:

1	2	3	4	5	6	7	8	9	10
1	0	0.3	0.4	0	0.2	0.6	0.5	0	0
0	0	0.4	0.9	0	0.2	0.7	0.4	0	0

The above string is assumed that there was a total of 10 points. Vehicle after leave the depot (point 1) visited five-point, 8, 7, 6, 4 and 3. But the places visited by visiting their priorities sorted out the string shown in the first row can be identified. In this case the vehicle after leaving the depot point 6 visits the 3-point and visit 4-point and 8-point and 7-point. In each of the percentage of requests that meet their answer string is shown in the second row. It should be noted that if a vehicle is used for all values in the field will be zero

Calculate the target function:

The first target function is calculated for each path is determined by the cost of each vehicle route will be calculated. The sum of these costs for different vehicles to determine the routing cost.

Then the request is fulfilled to be determined from anywhere. If the demands are not met one point, the level of unmet demand in the second part is the objective function. On the other hand, according to a defined sequence, the algorithm does not have to comply with vehicle capacity constraints. The reason for this increase is the search algorithm. Therefore, if the vehicle is carrying more than its capacity dependent on the function imposed excess fines. This factor is 10,000 fine on all issues.

Crossover and mutation

Junction between two different answers to a point of intersection method is used so that a sequence selected from each parent and according to a specified point in both fields is divided into two parts. Then each child a piece of string first parent and the other parent inherit a piece of string. In addition to creating mutations, chromosome mutations per generation, which occurs with probability 50% amputation in the cell is selected from a field whose value varies randomly. 5. Compare the performance of the genetic algorithm with the exact solution to investigate the genetic algorithm used for this, the algorithm is coded in MATLAB 2011. After 10 it is produced in various sizes in these examples of the application of the uniform distribution with lower bound of 1000 and 2000 is an upper bound. Each point in two-dimensional space with a length of 150 and 150 are located within and the cost of travel between any two points is corresponding to the distance between the two points is considered. Capacity between 8000 and 15,000 vehicles at random is obviously intended capacity vehicles are elected the total capacity of the vehicle is greater than the sum of the demand points. Additional information is shown in the following table.

Table 1. Compare the performance of the genetic algorithm with the exact solution.

No problem	n	k	γ_1	γ_2
PR1	6	2	30	2
PR2	10	2	30	10
PR3	20	3	25	15
PR4	30	5	20	20
PR5	40	10	20	25
PR6	50	12	15	10
PR7	70	15	15	20
PR8	100	20	10	30
PR9	150	30	10	40
PR10	200	40	5	40

The results of exact solution generated by GAMS software such as genetic algorithms have been compared with the results.

Since that time GAMS software solution for high-dimensional problems is high time limit is 3600 seconds, or 1 hour it is considered. It should be noted that if the problem is in the GAMS software is required when more than 1 hour to reach a feasible solution (not necessarily optimal) has to offer and the program ends.

The following table summarizes the results of the comparison with the genetic algorithm is presented GAMS software

Table 2. Results of the comparison with the genetic algorithm.

No problem	Accurate solutions with GAMS software		Genetic Algorithm		Genetic Algorithm error
	Target function	Time resolved	Target function	Time resolved	
PR1	13350	0/3	13350	11/43	0
PR2	15976	2/4	15976	13/9	0
PR3	29864	10/7	29950	15/9	0/002871452
PR4	47968	34/2	57694	24/8	0/168579055
PR5	76015	106/1	83948	36/9	0/094498976
PR6	126975	539/7	149585	54/7	0/151151519
PR7	249873	1489/3	284570	73/9	0/121927821
PR8	589640	3600	551980	94/7	0
PR9	759316	3600	759573	129/7	0
PR10	957400	3600	906480	186/1	0
Middle	286637/7	1298/27	285310/6	64/203	0/053902882

As can be seen in the table above GAMS software failed in the last issue in less than 1 hour to find the optimum solution but for this example, the genetic algorithm is able to spend less time to find better solutions than GAMS. The chart below shows the resolve of both methods.

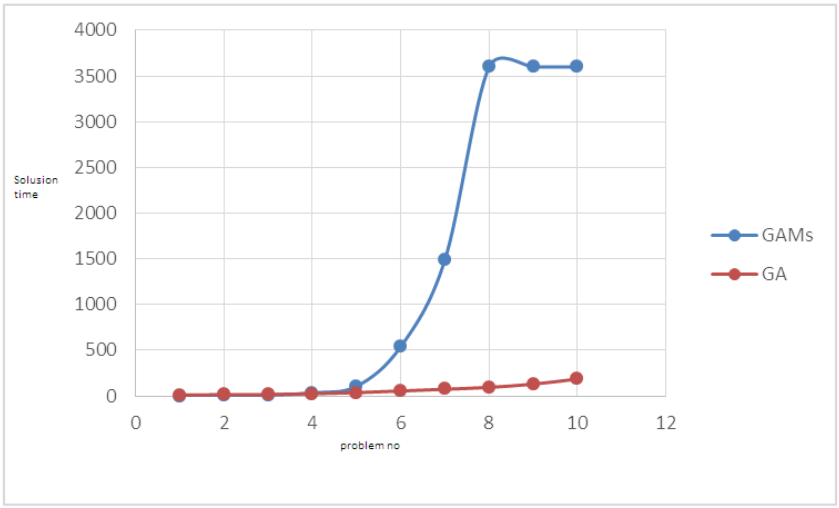

Figure 3. Resolve of genetic algorithm VS GAMS.

As you can see, the exact solution of this problem has increased exponentially with the GAMS software by increasing the magnitude of the problem solution time increases dramatically. However, the genetic algorithm to solve the rate of increase is very small in the following chart, the objective function obtained from the exact solution and meta-heuristic solving the model shown.

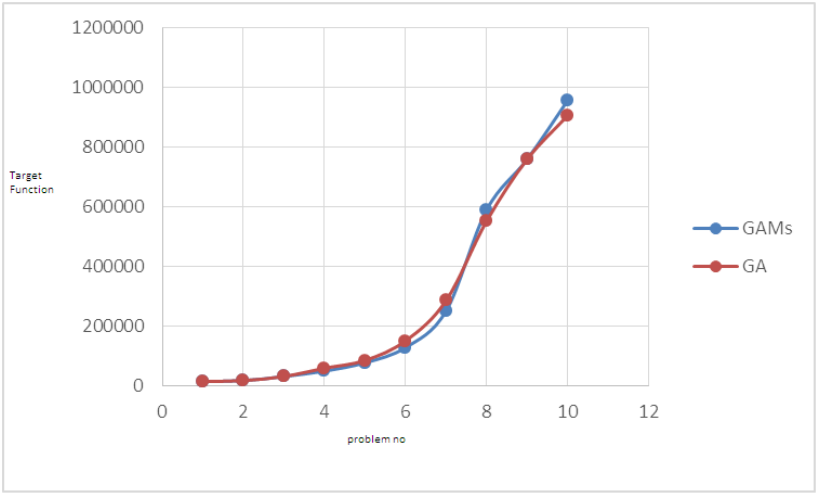

Figure 4. Exact solution of the problem has increased exponentially with the GAMS software by increasing the magnitude of the problem solution time increases.

The figure above shows the various issues which genetic algorithms are not that different from the exact solution. And the whole problem is solved with GAMS software error is 0.05% this reflects the good performance of genetic algorithms to find the optimal solution is the problem.

6. CONCLUSIONS

In this paper, an integer linear model is presented to solve the problem of routing vehicles. The model assumes the selection of vehicles for the use of the limited capacity of each of them was considered significant. The purpose of this model at the same time, travel costs and demands are not met which is always in the opposite direction each other. In other words, the lower the demands are not met travel expenses will be higher. A genetic algorithm was presented to solve the model [8].

7. SUGGESTIONS FOR FUTURE RESEARCH:

For future studies in this area are concerned with the potential demand in different periods taken into account. The following restrictions have been removed tours and tours may be defined as the set of nodes each tour routes in the modeling.

REFERENCES

[1] Ombuki-Berman, Beatrice, Hanshar, Franklin T., " Using Genetic Algorithms for Multi-depot Vehicle Routing", SCI 161, pp. 77–99., Berlin, 2009.
[2] Eksioglu, Burak, Volkan Vural, Arif, Reisman, Arnold., " The vehicle routing problem: A taxonomic review", Computers & Industrial Engineering, Vol. 57, pp. 1472–1483, 2001
[3] Hoff, A., Andersson, H., Christiansen, M., Hasle, G., and Løkketangen, A., “Industrial aspects and literature survey: Fleet composition and routing”, Computers & Operations Research, Vol. 37, No. 12, pp. 2041-2061, 2010.
[4] Soonpracha, K., Mungwattana, A., Janssens, G. K., and Manisri, T. “Heterogeneous VRP Review and Conceptual Framework”, Proceedings of the International MultiConference of Engineers \ and Computer Scientists, Vol. 2, pp., 2014.
[5] Toth, P. and Vigo, D., “A heuristic algorithm for the symmetric and asymmetric vehicle routing problems with backhauls”, European Journal of Operational Research, Vol. 113, No. 3, pp. 528-543, 1999.

[6] Bozorgi-Amiri, Ali, M. S. Jabalameli, and SMJ Mirzapour Al-e-Hashem. "A multi-objective robust stochastic programming model for disaster relief logistics under uncertainty." OR spectrum 35.4 (2013): 905-933.
[7] Haghani A, Oh SC. Formulation and solution of a multi-commodity, multimodal network flow model for disaster relief operations. Transportation Research A 1996;30(3):231e50.
[8] Liu, R., Xie, X., Augusto, V., and Rodriguez, C., "Heuristic algorithms for a vehicle routing problem with simultaneous delivery and pickup and time windows in home health care", European Journal of Operational Research, Vol. 230, No. 3, pp. 475-486, 2013.