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Vehicle route scheduling and transportation cost minimization in a latex industry using PSO

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ABSTRACT *: The vehicle route scheduling problem is concerned with the determination of routes and schedules for a fleet of vehicles to satisfy the demands of a set of customers. The goal of vehicle routing is to schedule multiple suppliers from various places. Vehicle routing has existed since the advent of the Industrial age, when large-scale production became possible. As the complexity and scale of the manufacturing world increased, the task of optimizing vehicle routing grew. The vehicle routing problem is a combinatorial optimization and integer programming problem seeking to service a number of customers with a fleet of vehicles. Often the context is that of delivering goods located at a central depot to customers who have placed orders for such goods or vice-versa. Implicit is the goal of minimizing the cost of distributing the goods. Many methods have been developed for searching for good solutions to the problem, however even for the smallest problems, finding global minimum for the cost function is computationally complex. The paper presents an optimization algorithm using Particle Swarm Optimization (PSO) for the vehicle routing that would enable the logistic manager of a latex industry to minimize the transportation cost and maximize the collection using minimum number of vehicles.*

Keywords – *Vehicle route scheduling, transportation cost, Particle Swarm Optimization*

I. INTRODUCTION

Vehicle route scheduling and cost minimization of a latex industry with a capacity to process 1000 barrels of normal latex a day and 17460 M.T. per year has been considered in the present paper. The factory collects rubber latex from 143 permanent collection centers located around 200 kilometers from the factory in addition to few non-permanent suppliers. The company uses about 30 vehicles on an average per trip. The collection capacities of these vehicles vary from 24 to 65 barrels (4800kg -13,000kg). The charge per kilometer of these vehicles depends on their carrying capacity. A manual procedure of vehicle route allotment is in practice in the organization, for which the efficiency cannot be predicted. Hence a stochastic procedure for optimization is considered for vehicle route scheduling of the organization.

Genetic algorithm for solving capacitated vehicle routing problem are reported that are mainly characterized by using vehicles of the same capacity based at a central depot that will be optimally routed to supply customers with known demands. The algorithms are used to find an optimal set of delivery routes satisfying the requirements and giving minimal total cost [1, 2].

An iterative route construction and improvement algorithm for the vehicle routing problem with soft time windows is presented by Miguel [3]. This paper presents a problem with practical applications in distribution and logistics due to the rising importance of just-in-time procedure.

A particle swarm optimization algorithm for open vehicle routing problem (OVRP) presented by Mir Hassani [4] reports that in OVRP a vehicle does not return to the depot after servicing the last customer on a route. Studies on solving the capacitated vehicle routing problem by Jin Ai [5] presents two solution representations and the corresponding decoding methods for solving the problem using particle swarm optimization. In problems where the customers require not only the delivery of goods but also the simultaneous pick up of goods, a general assumption is that all delivered goods originate from the depot and all pickup goods must be transported back to the depot [6].

Literatures on solving vehicle routing problems using Ant Colony Optimization (ACO) algorithm constructs a complete tour for the first ant prior to the second ant starting its tour [7].Once the vehicle capacity constraint is met, the ant will return to the depot before selecting the next customer. This selection process continues until each customer is visited and the tour is complete.

A heuristic approach for solving large scale bus transits vehicle scheduling problem with route time constraints is presented by Ali Haghani., & Mohamaadreza Banihashemi [8]. They conducted a study of multiple depots with time window, with the constraint of restriction fuel efficiency. Russel Eberhart, Balter and

James Kennedy reviewed the PSO concept and introduced a new form of particle swarm optimizer [9]. They examined how changes in the procedure affect the number of iteration required to meet an error criterion, and the frequency with which models interminably around a new optimum. In the binary version, trajectories are traced in the probability that a co-ordinate will take on a zero or one value. Yuhui Shi and Renhart W introduced a new parameter "inertia weight" in to the original PSO [10]. It is proved that PSO with inertia weight will have better performance and has a bigger chance to find the global optimum within a reasonable number of iterations. A large inertia weight facilitates a more powerful global search while a small inertia weight facilitates a more powerful local search Yuhuishe, Russell and Engelbrecht AP conducted empirical studies on the performance of PSO and found that PSO converges very quickly towards the optimal positions but may slow its convergence sped when it is near a minimum [11]. Also proved that using an adaptive inertia weight, performance of PSO near optima can be improved. PSO may lack global search ability at the end of a run due to the utilization of a linearly decreasing inertia weight they implemented a Fuzzy system to dynamically adjust the inertia weight in order to improve the performance of the PSO.

II. MATHEMATICAL MODELING

A mathematical model for developing the optimization algorithm is explained in the subsequent section. Objective is to Objective is to minimize

$$\sum_{k=1}^{K}\sum_{i=0}^{N}\sum_{j=0}^{N} C_{ijk} X_{ijk} \quad (1)$$

Subjected to the constraints:

$$\sum_{k=1}^{K}\sum_{i=0}^{N} X_{ijk} = 1, \quad j = 1,2,\dots\dots, N \quad (2)$$

$$\sum_{k=1}^{K}\sum_{j=0}^{N} X_{ijk} = 1, \quad i = 1,2,\dots\dots, N \quad (3)$$

$$\sum_{i=0}^{N} X_{itk} - \sum_{j=0}^{N} X_{tjk} = 0, \quad k = 1,2,\dots\dots, K; t = 1,2,\dots\dots, N \quad (4)$$

$$\sum_{i=0}^{N}\sum_{j=0}^{N} d_{ijk} X_{ijk} \le D_k, \quad k = 1,2,\dots\dots, K \quad (5)$$

$$\sum_{j=0}^{N} q_j \left(\sum_{i=0}^{N} X_{ijk} \right) \le Q_k \quad k = 1,2,\dots\dots, K \quad (6)$$

$$\sum_{j=1}^{N} X_{0jk} \le 1, \quad k = 1,2,\dots\dots, K \quad (7)$$

$$\sum_{i=1}^{N} X_{i0k} \le 1, \quad k = 1,2,\dots\dots, K \quad (8)$$

$$\sum_{i=1}^{N} q_i \le \sum_{k=1}^{K} Q_k, \quad (9)$$

$$X_{ijk} \in \{0,1\}, \quad i, j = 0,1,2,\dots\dots, N; k = 1,2,\dots, K \quad (10)$$

$$X_{ijk} = {}^{1\ if\ vehicle\ k\ travels from\ customer\ i\ to\ j,}_{0 = otherwise} \quad (11)$$

Where depot is represented by node 0,

No. of collection centers =N,

No of vehicles=K,

Quantity of rubber latex at customer "*i*" = q_i

Capacity of k^{th} vehicles= Q_k

Maximum allowable distance by vehicle k =D_k

Cost of traveling from customer *i* to *j* by vehicle *k*= C_{ijk}

The basic process of the PSO algorithm is given as follows.

Step 1: (Initialization) randomly generate initial particles.

Step 2: (Fitness) Measure the fitness of each particle in the population.

Step 3: (Update) Compute the position vector of each particle with Eq. (12).

Step 4: (Construction) for each particle, move to the next position according to Eq. (13).

Step 5: (Termination) Stop the algorithm if termination criterion is satisfied; return to Step 2 otherwise.

$$V_{id}^{t} = V_{id}^{t-1} + c_1 r_1 (P_{id}^{t} - x_{id}^{t}) + c_2 r_2 \left(P_{gd}^{t} - x_{id}^{t}\right) \qquad (12)$$

$$\mathrm{d} = 1, 2, 3 \ldots \ldots . . \mathrm{D}$$

$$X_{id}^{t+1} = X_{id}^{t} + V_{id}^{t} \qquad (13)$$

$$\mathrm{d} = 1, 2, 3 \ldots \ldots . . \mathrm{D}$$

P_{id}^{t} is the best position of the particle

P_{gd}^{t} is the global best position of particle

x_{id}^{t} is the position of the previous particle

where c_1 indicates the cognition learning factor; c_2 indicates the social learning factor, and r_1 and r_2 are random numbers

In the present analysis, first the population of particles is initialized, each particle having a random position within the dimensional space and a random position vector for each dimension. Second, each particle's fitness for the vehicle routing problem is evaluated. If the fitness is better than the particle's best fitness, then the position vector is saved for the particle. If the particle's fitness is better than the global best fitness, then the position vector is saved for the global best. Finally the values are updated until the termination condition is satisfied

PSO algorithm can be described as follows.

$$V_{local\ best} = \propto \times\, x_{local\ best} + \beta \times (1 - x_{local\ best}) \qquad (14)$$

$$V_{global\ best} = \propto \times\, x_{global\ best} + \beta \times \left(1 - x_{global\ best}\right) \qquad (15)$$

$$V = w \times V + c1 \times V_{local\ best} + c2 \times V_{global\ best} \qquad (16)$$

Where $\alpha + \beta = 1, 0 < \alpha, \beta < 1$ are control parameters which indicate the control degree of $\boldsymbol{V}$. $w+c1+c2=1$, $0< w, c1, c2<1$.In Equation (16), the first part represents the inertia of previous probability; the second part is the "cognition" part, which represents the local exploration probability; the third part is the "social" part, which represents the cooperation among all quantum particles.

Fitness is used to evaluate the performance of particles in the swarm. Generally, choosing a proper objective function as fitness function to represent the corresponding superiority of each particle is one of the key factors for successful resolution of the relevant problem using PSO algorithm. In the capacitated vehicle routing problem, the objective is to minimize the total cost or distance. Therefore, according to the description in above section, the following equation as fitness function has been selected:

$$Fit. = \sum_{k=1}^{K} \sum_{i=0}^{N} \sum_{j=0}^{N} C_{ij} X_{ij}^{k} \qquad (17)$$

The objective of the scheduling is to minimize the total cost, i.e. *fit*, so the particle with the minimal fitness will outperform others and should be reserved during the optimization process.

III. SOLUTIONS USING PSO

A MATLAB program has been initially developed to calculate the least travelling cost of two vehicles between eight destinations. The program is initiated with the capacity and kilometer cost of each vehicle whereas the number of barrels to be collected from each places and the distance between the destination and depot are fed in the form of excel sheet.

The program works on the basis of permutations of 8 destinations. According to this, in case one, the first node is visited by the first vehicle and all the other nodes are visited by the second vehicle. For the second case, the first two nodes are visited by the first vehicle and rest is covered by the second vehicle. Similarly, all cases are considered and the cost for each is evaluated based on the various parameters given. At last the route with least route cost is found out.

An algorithm is developed based on PSO for two vehicles and eight destinations. After ensuring its acceptable agreement with the exact solutions, the algorithm in PSO is also extended to solve the present problem with 30 vehicles and 143 destinations for which the route of one vehicle of a particular trip is shown in Table 1.

59	61	62	63	64	65	66	67	68	69	70	71	72	60	73	74	75	76	77	78
1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

99	100	101	102	103	104	105	106	107	108	109	110	111	112	113
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

114	115	116	117	118	119	120	121	122	123	124	125	126	127	128
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

129	130	131	132	133	134	135	136	137	138	139	140	141	142	143
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

46	47	48	49	50	51	52	53	54	55	56	57	58	104414.54
0	0	0	0	0	0	0	0	0	0	0	0	0	

Table 1. Results for the month of June using PSO

Demands vary with the seasons and environmental conditions. These varying demand requirements were considered and the corresponding plans for each of the cases are obtained using the proposed PSO algorithm. The algorithm is used to compute the optimum route to perform all deliveries. The plans generated by the algorithm are compared with the plans made manually in the company. Table 2 shows the cost estimation using the proposed and existing methods. The PSO algorithm - implemented in Matlab - provided a good solution in two-three minutes on a Pentium PC at 1 GHz. It is found that the proposed PSO algorithm can provide a better solution for the present problem faced by the organization in connection with vehicle routing. The algorithm allows a reduction of Rs.3, 00000/- per year in cost.

Month	Cost in Rs.	
	Proposed Method	Existing method
JAN	124894	149894
FEB	123736	148736
MAR	120370	145370
APRIL	105500	130500
MAY	116000	141000
JUNE	104415	129415
JULY	107794	132794
AUG	116794	141794
SEP	120662	145662
OCT	120370	145370
NOV	122737	147737
DEC	124223	149223
Total Transportation Cost (in Rs.)	**1407494/-**	**1707494/-**

Table 2. Cost estimation using proposed and existing methods

IV. CONCLUSION

A PSO algorithm has been developed for vehicle route scheduling and transportation cost minimization of latex industry. The algorithm has been initially used for 2 vehicles and 8 destinations and the obtained results are compared with the exact solution. The result obtained by the PSO algorithm has been in good agreement. The ruggedness of the algorithm is ensured by varying the vehicle capacities and comparing the same with exact solutions. The effectiveness of the proposed algorithm has been proved from the above comparisons. Thereafter, the algorithm is extended to solve the vehicle routing problem of the latex industry under consideration, with 30 vehicles and 143 destinations. Travelling cost of the proposed method is obtained for all the months and is compared with the manual method. The algorithm allows a reduction of Rs.3, 00000/- per year in cost. It is found that the PSO algorithm presented in the paper provide a better solution for the vehicle routing challenges faced by the organization.

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