RESEARCH ON MULTI-DEPOT VRPTW OF OPTIMIZING BASED ON HIERARCHY CLUSTERING METHOD AND HGA FOR ELECTRONIC COMMERCE

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Abstract:

The traditional vehicle scheduling is not easy to satisfy with the real demand of logistics distribution under electronic commerce. Therefore, according to the particularity of logistic distribution under electronic commerce, multi-depot vehicle routing problem with time windows model is built. For MDVRPTW is NP puzzle, the improved Two-Phase Algorithm needs to be adopted to get solutions. Namely, the customer group can be divided into several regions using hierarchy clustering method in first phase. In the second phase, optimize the line of each single VRPTW model according to customers' dot in each group. Therefore, hybrid genetic algorithm is used to get the optimization solution. Use dualistic coding to deal with the time constrain of VRPTW problem, which can makes the problem simpler. Use improved saving algorithm to construct initial solution to improve the genetic low's searching efficiency. Using the best retain select method to ensure the diversity of groups. Improved ordinal crossover operators can avoid destroying good gene parts during the course of ordinal crossover. Adopt partial route overturn mutation operator to improve convergent speed. In the end, the test proves the validity of this improved algorithm combining with examples.

Keywords:

Electronic commerce; Multi-depot; Vehicle routing problem with time window; Hierarchy clustering; Hybrid genetic algorithm; Improved two-phase algorithm

1. Introduction

VRPTW is a typical NP puzzle. Its research method mainly includes accurate algorithm and intelligent optimization algorithm. Accurate algorithm can be divided into three types of direct tree searching algorithm and dynamic programming method and integer linearity programming [1].

Intelligent optimization algorithms mainly include tabu search method, simulated annealing algorithm, ant colony algorithm, and genetic algorithm etc. For example, Band got the solution of VRPTW problem by tabu search algorithm [2]. Osman solved combination optimization problem through simulated annealing algorithm [3]. LIU Zhi-shuo proposed adaptive hybrid ant colony algorithm based on flexible solution of two-phase strategy [4]. Genetic algorithm has good characteristics of getting solutions of combination optimization problem. Joe got solutions of multi-objective VRPTW problem based on minimum vehicle and total cost by genetic algorithm [5]. WU Jing-li constructed improved genetic algorithm through introducing cross operator [6].

Electronic commerce has the essential difference from traditional commercial activities. For MDVRPTW optimization under electronic commerce is a special problem that includes many aspects, hybrid strategy is usually introduced to classify and optimize route by two artificial intelligent methods. Ombuki proposed to classify route line by genetic algorithm [7]. And propose hybrid genetic algorithm to solve route optimization by tabu search algorithm method. Bent and Van Hentenryck minimized the vehicle amount by simulated annealing algorithm, and then reduced the transportation expense into the minimum dot by big field search method [8].

According to above analysis, the study proposes improved two-phase algorithm to solve problem when optimizing VRPTW under electronic commerce.

2. Mathematic model

$$Min \sum_{i \in s} \sum_{j \in s} \sum_{l,k \in V} C_{ijk}^{l} X_{ijk}^{l} d_{ij} + \sum_{i \in H} \sum_{l,k \in v} CC_{k}^{l} \max[a_i - s_{ik}^{l} + tt_i, 0] + \sum_{i \in H} \sum_{k,l \in v} CCS_{k}^{l} \max[s_{ik}^{l} - b_i + tt_i, 0] \quad (1)$$

Restraint condition,

$$\sum_{l,k \in V} \sum_{i \in s} X_{ijk}^{l} = 1, \quad j \in H \quad (2)$$

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$$\sum_{i\in H}\sum_{j\in s} q_i X_{ijk}^l \le w_k^l, \qquad l,k\in V \quad (3)$$

$$\sum_{l,k\in V}\sum_{i\in s} X_{ijk}^l d_{ij} \le D_k^l, \quad j\in H \quad (4)$$

$$s_{ik}^l + t_{ijk}^l - K(1-x_{ijk}^l) \le s_{jk}^l, i,j\in H, \quad l,k\in V \quad (5)$$

$$\sum_{i\in s} X_{ijk}^l = Y_{ik}^l, \quad j\in s, \quad l,k\in V \quad (6)$$

$$\sum_{j\in s} X_{ijk}^l = Y_{ik}^l, \quad i\in s, \quad l,k\in V \quad (7)$$

$$\sum_{r\in G}\sum_{i\in H} X_{rik}^l \le 1, \qquad l,k\in V \quad (8)$$

$$a_i \le s_{ik}^l + tt_i \le b_i, \qquad i\in H, \quad l,k\in V \quad (9)$$

$$t_{ijk}^l = {d_{ij}}\Big/{\bar{v}}, \qquad i,j\in H, \quad l,k\in V \quad (10)$$

$$X_{ijk}^l = 0,1 \quad \mathrm{i,j}\in \mathrm{s}, \quad l,\mathrm{k}\in \mathrm{V} \quad (11)$$

$$Y_{ik}^l = 0,1 \qquad i\in H, \qquad l,k\in V \quad (12)$$

In formula:

t_{ijk}^l is the time of the types l vehicles from the customer k to the customer j ; s_{ik}^l : is the start time of the type l vehicles k to customer i ; CC_k^l : is the waiting cost of type l vehicle k ; CCS_k^l is the delay fee of type l vehicle k ; a_i : The earliest start time of customer $i(i\in H)$; b_i : the latest finish time of customer $i(i\in H)$; $\bar{v}$: vehicle average speed; tt_i unload time of customer i ; $G\{g_r|r=1,...,R\}$: A series of feasibility R distribution center set; $H\{h_i|i=R+1,...,R+N\}$: A series of feasibility N customers set; $S\{G\}\cup\{H\}$: the sum of all distributions and customers. $V\{v_{lk}|l=1,...,L \quad k=1,...,K\}$: the set of type l transport vehicle K ; C_{ijk}^l :The average unit cost of transportation distance of type l vehicle k from customer i to customer j ; q_i : the requirement amount of customer $i(i\in H)$; W_k^l :carrying capacity of vehicle type $l(l=1,...,L)$; d_{ij} : the Straight-line distance from customer i to customer j ; D_k^l : the maximum running distance of type l vehicle k .

In formula (2), the target function can get the minimum value of total cost; constrain condition(5) can make sure type l vehicle k on the tour from customer i to customer j , cannot get to the destination before $s_{ik}^l + t_{ijk}^l$; constrain condition(9) make sure vehicle can satisfy time window condition on their way; constrain condition (10) shows time of customer i to customer j equals the distance from point i to point j divide speed $\bar{v}$.

3. Grouping algorithm based on clustering and scanning

3.1. Hierarchy clustering algorithm step

The calculation method of similarity measurement $\Delta(c_i,c_j)$ between clustering group c_i and c_j is the basis of clustering method. The point with no longer distance can be gathered so as to the same vehicle pass. The classified distance adopts generalized distance $\Delta(c_i,c_j)=\min_{a\in c_i,b\in c_j} D(a,b)$. Here, $D(a,b)$ is the sample distance measurement as the shortest distance. After make certain similarity measurement, hierarchy clustering algorithm can be described as the following.

Step one: Suppose $c_j = y_j, j\in\{j=1,2,...,n\}$. Here, c_j represents different clustering group, n is the customer amount. Namely, firstly classify every customer into one group.

Step two: Clustering muster c_k and c_l can be found in $\{c_l|l\in I\}$, which can satisfy condition $\Delta(c_k,c_l)=\min_{\forall j,i\in I}\Delta(c_j,c_i)$. Here, $\Delta(c_k,c_l)$ is the similarity measurement between c_k and c_l .

Step three: c_i can be combined into c_k and get rid of c_i .

Step four: i can be gotten rid from index group I. If radix of I equals to satisfied number, the calculation can be stopped. Otherwise, enter into step two.

3.2. Scanning based on restraint condition

Step one: Random select a division from former clustering.

Step two: Distribution center can be used as origin of polar coordination. The line connecting customer point and origin in connecting picture can be defined as zero angles so as to establish polar coordination.

Step three: Transfer the position coordination of selected customer. They all are transferred into polar coordination.

Step four: Begin with minimum angle customer and establish group. Add the customer into the group one by one according to anticlockwise direction until the customer restraint go beyond restraint condition.

Step five: If going beyond, establish a new group and continue adding the customer into the group according to anticlockwise direction.

Step six: Repeat forth step process until all customers can be divided into some groups.

4. Application of hybrid genetic algorithm in VRPTW

4.1. Genetic code

Dualistic coding method can be shown in the following table. Individual chromosome represents that dualistic coding are composed of variable code and additional code. Upper line $s(i)$ is the additional code $s(i)=j$ of variable $x(j)$. Below line is the corresponding additional code $s(i)$ value of variable $x_{s(i)}$.

Table 1. Dualistic coding

Additional coding	$s(1)$	$s(2)$	…	$s(i)$
Variable coding	$x_{s(1)}$	$x_{s(2)}$	…	$x_{s(i)}$

To code each individual, firstly, additional code $\{s(i), i=1,2,...n\}$ is randomly produced by riffle mode and it is arranged to upper line. Variable code number (0 or 1) also is randomly produced in below line. Thus, form into each dualistic code.

Namely, consider the customer of additional code $s(i)$ according to sequence. If dealing with customer disobeys the time restriction condition, force the variable of customer become into zero. Otherwise, variable number $p_{s(i)}$ of customer is 1 till all customers are all deal with.

Table 2. Dualistic decoding

Additional coding	$s(1)$	$s(2)$	…	$s(i)$	…
Variable decoding	$p_{s(1)}$	$p_{s(2)}$	…	$p_{s(i)}$	…

The step of decoding algorithm is shown as followings.

Step1: $s=0, sum=0$;

Step2: If $x_{s(i)}$ =0, $p_{s(i)}$ =0, and execute step 4. Otherwise, execute step 3.

Step 3: if $e_i \le$ $sum + a_{s(i)} \le l_i$, $p_{s(i)}$ =1 and $sum = sum + a_{s(i)}$. Otherwise, $p_{s(i)}$ =0.

Step 4: $i=i+1$ .If $i \le n$, return step 3; Otherwise, it finishes.

According to dualistic coding, operators of crossover and mutation operation need to design again.

4.2. Forming initial solutions

Set $s(i,j)$ as saving value after connecting. Get $s(i,j)=c_{0i}+c_{0j}-c_{ij}$, TT^{ll} indicates the delay value (or early value) of the vehicle getting to the customer j than the vehicle on the original route getting to the customer j after customer i connect to customer j on the route ll , get $TT^{ll}=s_{ik}^{l}+tt_i+t_{ijk}^{l}-s_{jk}^{l}$, if TT^{ll} =0, means the time getting to the customer does not changed. When $TT^{ll}<0$, which means the time getting to the customer earlier than expected. Otherwise, $TT^{ll}>0$ means time delay of getting to the customer j .

When considering connection spot i and connection spot j , we need check out if it Consistent with constrains of time window. When $TT^{ll}<0$, if $\left|TT^{ll}\right| \le \nabla_j^-$, means the assignment of vehicle after customer j does not need wait. Otherwise wait; when $TT^{ll}>0$, if $TT^{ll} \le \nabla_j^+$, there is no delay of the assignment of the vehicle after the customer j . Otherwise it is delays.

Step1: calculate the saving value $s(i,j)$ after the customer i connect to the j , set $M=\{s(i,j)|s(i,j)>0\}$, and make sort of $s(i,j)$ from small to big in the M .

Step 2: if $M=\phi$, terminated, otherwise to first item $s(i,j)$, inspect corresponding (i,j) , if satisfied one of the following conditions. Turn in to Step 4, otherwise turn into next Step.

(1) Nether Spot i nor spot j on the route ll ;

(2) Spot i does not on the route ll , spot j is the start point of route ll ;

(3) Spot i does not on the route ll , spot j is the finish point of route ll ;

(4) spot i is the finish point of route ll ; spot j is a start point of another route;

Step 3: determine if or not spot i and spot j known exchange. If there is no exchange, turn into Step2, otherwise turn into Step7;

Step4: calculate the total cargo Q on the route ll after customer i connected to the customer j . If $Q \le W_k^l$, turn into next Step, otherwise turn into Step 7;

Step 5: calculate TT^{ll} ;

(1) if TT^{ll} =0, turn into Step 6;

(2) if TT^{ll}<0, calculate ∇_j^-,if $\left|TT^{ll}\right| \le \nabla_j^-$, turn into next Step, otherwise turn into Step 7;

(3) if $TT^{ll} > 0$, calculate ∇_j^+ , if $TT^{ll} \le \nabla_j^+$,turn into next Step, otherwise turn into Step 7;

Step 6; make connection between customer i and customer j , calculate the new time of the vehicle getting to the new assignment. Turn into next Step;

Step 7: set the value of $s(i, j)$ is 0. Turn into step 1.

4.3. Selecting operator

In order to keep whole searching ability and enlarge group diversity, the study proposes a best preserving selection algorithm combining best individual preserving and roulette selection. The concrete steps are as followings.

Step 1: Calculate the fitness value f_i of each individual for community. Suppose that the highest fitness value of actual group is f_{best} .

Step 2: Calculate the total fitness value $\sum f_i$.

Step 3: Calculate the corresponding fitness value $p_i = \frac{f_i}{\sum f_i}$ of each individual in community.

Step 4: Randomly create α in [0,1]. If $p_1 + ... + p_{i-1} < \alpha < p_1 + ... + p_{i-1} + p_i$, select individual i enter into the next generation community. Repeatedly select n times, and generate n individuals of next generation.

4.4. Cross operator

If all chromosome crossover dots are not zero, good gene will be destroyed when ordinal crossover. It cannot guarantee that algorithm is convergent to the optimization. Therefore, ordinal crossover operation is improved in order to keep the part of good gene of parents and get the optimization as whole. The concrete operations can be shown as followings.

Step 1: Randomly select one part as crossover part from two father chromosome.

Step 2: If two genes at chromosome crossover dot are zero, directly have crossover operation.

Step 3: If genes at chromosome crossover dot are all zero, move the crossover dots to the left (right) till genes at left and right crossover dot are all 0.

Comparing with standard ordinal crossover operator, improved crossover operator can make chromosome of filial generation inherit more gene information of father generation so as to guarantee the algorithm convergent. Therefore, ability of searching optimization solution is stronger than standard ordinal crossover operator.

4.5. Mutation operator

Mutation operation can adopt partial route overturn mode. Its operation mode is selecting two points randomly in gene chain to keep the outside order. Overturn the tow order points again. The recombining result can take as gene after mutation.

After test, partial route overturn mutation mode is favor to partial optimization solution. And this operation can obviously improve total algorithm efficiency.

4.6. Hybrid genetic algorithm step

Step 1: g_{en}=0, use natural number coding method, construct initial group, and then input control parameters; crossover operator p_c, The initial mutation operator p_m, group size N, Maximum operating algebra $\max g_{en}$;

Step2: calculate each individual Relative fitness value $p_i = \frac{f_i}{\sum f_i}$ in the group.

Step3: if $g_{en} < \max g_{en}$, $g_{en} = g_{en} + 1$,turn into Step4, otherwise stop the calculation, and output the best solution;

Step4: Retain the best option of operating

Step5: improved sequence crossover;

Step6: start 2-exchange Mutation operation;

Step7: the number of Initial cycle's variable $t = 1$, the best solution at present $s^* = s$, and the length is $l(s^*)$;

Step8: random select 2 top point x_i, x_j in the optimal route, and $i < j$, x_i, x_j nonadjacent;

Step9: calculate saving distance $\Delta c = \{d(x_{i+1}, x_j) + d(x_i, x_{j+1})\} < \{d(x_{i+1}, x_i) + d(x_j, x_{j+1})$, if $\Delta c > 0$, no exchange, $t = t + 1$,turn into Step11, otherwise doing exchange, the relative solution is s' , the optimal solution is $s^* = s'$, $t = 1$, turn into Step8;

Step 10: if there is no reduce of $l(s^*)$ after x loops, this algorithm is finished, otherwise turn into Step8;

Step11: repeat Step7-10, until getting to a certain exchange times;

Step12: repeat Step 2-11.

5. Experiment calculation and result analysis

The data of the paper is from reference materials [4], and adopted. The Logistics center has 5 delivery vehicles, the max load ability of the vehicle is 8t, and each max delivery distance is 500km, service 20 customers. The coordinate of the logistic center is (145km, 130km), (38km, 60km). The average speed of the vehicle is 60.0km/h. the coordinates of the customers and cargo requirement, and time window limits as Table 3. Use Straight-line distance between customers and customers to center.

Table 3. Experiment data

Customer	X-coordinate	Y-coordinate	Demand	ET	LT
1	128	85	0.1	0.5	5.5
2	184	34	0.4	1.0	8.0
3	154	166	1.2	0.0	5.5
4	189	152	1.5	0.5	4.5
5	155	116	0.8	0.0	5.0
6	39	106	1.3	1.0	7.5
7	106	76	1.7	0.5	7.0
8	86	84	0.6	0.5	3.0
9	125	21	1.2	1.0	5.0
10	138	52	0.4	0.5	4.0
11	67	169	0.9	1.0	5.0
12	148	26	1.3	1.0	8.0
13	18	87	1.3	1.0	5.0
14	171	110	1.9	0.0	10.5
15	7.4	10	1.7	1.5	3.5
16	2.0	28	1.1	2.0	10.0
17	119	198	1.5	0.5	6.5
18	132	151	1.6	0.0	5.5
19	64	5.6	1.7	1.0	7.5
20	96	148	1.5	0.5	8.5

5.1. Group classification

(1) Determine Category number by the delivery centers.

(2) Use k-means clustering method, divide customers into 2 classes.

First class: 6, 13, 15, 16, 19, 8; corresponding delivery center coordinate (38km, 60km).

Second class: 1, 2, 7, 8, 9,10,12,3,11,17,18,20,4,5,14; Corresponding delivery center coordinate (145km, 130km).

(3) Set delivery center as the pole, establish individual Polar coordinates.

5.2. Classification adjustment

The adjust consequence as follows:

To first class: 6,13,15,16,19,8, doing scan, correspond with the constrains conditions of the vehicle carrying ability, To second class: 1,2,7,8,9,10,12,3,11,17,18,20,4,5,14, divide into 2 groups. First group: 1,2,7,9,10,12,5,14; Second group: 3,4,11,17,18,20.

After scanning on the first group which consistent with the vehicle carrying ability. After scan on the second group which does not consistent with the vehicle carrying ability. So it needs adjustment. There are 2 consequences after adjustment:

(1) Set customer number 4 as a group, the new groups are: Second group: 3, 11, 17, 18, 20; third group: 4.

(2) Set customer number 18 as a group. The new groups are: Second group: 3, 11, 17, 4, 20; third group 18.

5.3. Route optimization

The Computer calculation is by the compute with the CPU at 1.8 GHz and 512 Mb memories. Using following parameters: set group scale N=50, the largest number of iteration max $g_{en} = 200$, crossover operator $p_c = 0.80$, Mutation operator $p_m = 0.01$.

5.3.1 The Optimize results of scheme I

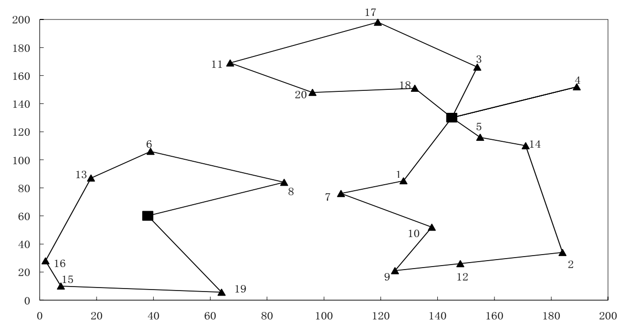

Figure 1. Optimization route of scheme I for multi-depot VRPTW

Table 4. Vehicle scheduling result of scheme I

Center	Vehicle route/ staring and reaching time	Running distance and loading capacity
(38,60)	D-8-6-13-16-15-19-D 0-0.895-1.76-2.23-3.25-3.50-4.51	53.7-51.9-28.3-61.1-18.8-56.8-60.3 7.7-7.1-5.4-3.7-2.6-1.3-0
	D-18-20-11-17-3-D 0-0.41-1.01-1.61-2.60-3.39-4.01	25-36-36-60-47-37 6.7-5.1-4.2-2.7-1.5-0
(145,130)	D-5-14-2-12-9-10-7-1-D 0-0.29-0.57-1.86-2.47-2.86-3.42-4.09-4.49-5.29	17-17-77.1-36.9-23.5-33.6-40-23.8-48.1 7.8-7-5.1-4.7-3.4-2.2-1.8-0.1-0
	D-4-D 0-0.82-1.64	49.2-49.2 1.5-0

Table 5. Route optimization result of scheme I

Center	Route	capacity/actual capacity	Total time	Total distance
(38,60)	D-8-6-13-16-15-19-D	7.7/8.0	5.52	330.9
	D-18-20-11-17-3-D	6.7/8.0	4.01	240.7
(145,130)	D-5-14-2-12-9-10-7-1-D	7.8/8.0	5.30	317.3
	D-4-D	1.5/8.0	1.64	98.4
Total/km		987.30		

5.3.2. The Optimize results of scheme II

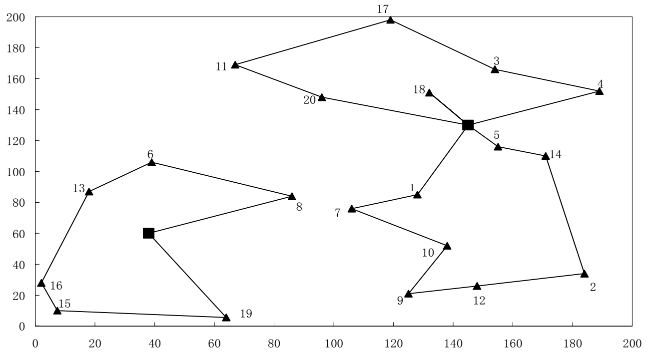

Figure 2. Optimization route of scheme II for multi-depot VRPTW

Table 6. Route optimization result of scheme II

Center	Route	capacity/actual capacity	Total time	Total distance
(38,60)	D-8-6-13-16-15-19-D	7.7/8.0	5.52	330.9
(145,130)	D-20-11-17-3-4-D	6.6/8.0	4.7	281.8
	D-5-14-2-12-9-10-7-1-D	7.8/8.0	5.30	317.3
	D-18-D	1.6/8.0	0.8	49.4
Total/km		979.40		

Table 7. Vehicle scheduling result of scheme II

Center	Vehicle route/ staring and reaching time	Running distance and loading capacity
(38,60)	D-8-6-13-16-15-19-D 0-0.895-1.76-2.23-3.25-3.5 0-4.51	53.7-51.9-28.3-61.1-18.8-56.8-60.3 7.7-7.1-5.4-3.7-2.6-1.3-0
(145,130)	D-20-11-17-3-4-D 0-0.87-1.47-2.46-3.25-3.88-4.70	52-36-60-47-38-49 6.6-5.1-4.2-2.7-1.5-0
	D-5-14-2-12-9-10-7-1-D 0-0.29-0.57-1.86-2.47-2.86-3.42-4.09-4.49-5.29	17-17-77.1-36.9-23.5-33.6-40-23.8-48.1 7.8-7-5.1-4.7-3.4-2.2-1.8-0.1-0
	D-18-D 0-0.41-0.82	25-25 1.6-0

5.4. Comparison with other algorithms

Table 8. Comparison among climb algorithm, genetic algorithm, simulated annealing algorithm, ant colony algorithm and this algorithm

Algorithm	2-OPT	GA	SA	AHACA	This algorithm
Average distance	1260.64	1328.62	1088.15	992.39	983.35
Average vehicles	4.3	4.5	4.0	4.0	4.0
Standard deviation of solution	103.48	65.25	41.67	12.87	5.59

6. Conclusions

It can be seen that improved two-phase algorithm has the characteristics of simply classification, clear and flexible as well as has the performance of part optimization and holistic seeking optimization. It is especially fit for distribution route optimization problem with time window, dispersive customer's order and strong area under electronic commerce.

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