A RESEARCH OF EMERGENCY LOGISTICS DISTRIBUTION VRP BASED ON SIMULATED ANNEALING ALGORITHM

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ABSTRACT:

In this paper,simulated annealing algorithm is studied and applied to the emergency logistics distribution vehicle routing optimization problem(VRP). In the process of disaster relief, the disaster relief control center makes the vehicle dispatch plan with the optimization result, then, not only the relief materials will be transported to the destination fast, but also the transportation cost will be cut down. Based on the mathematical description of the emergency logistics distribution VRP, the simulated annealing algorithm's mathematical model for solving this problem is established. Under the Visual C++ compile environment, a simulated sample is given, three random sampling methods are applied to this sample, by analying and comparing their result, it is found that different random sampling method directly affect the result, meanwhile, it shows that the result has global optimization characteristics, so that simulated annealing algorithm is superior to other optimization algorithms which are apt to fall into partial solution.

1. INTRODUCTION

China belongs to the countries where natural disasters frequently occur. Sudden outbursts of natural calamities cause great casualties and financial losses. Each year, government spends a large amount of social wealth on logistics activities of disaster relief[1]. In the course of disaster relief, emergency logistics should be distributed timely and economically. It means that, emergency logistics distribution[2] should be given a reasonable arrangement for dispatching vehicles, and be done its best to savings in cost under the premise of meeting the requirements of time.

Emergency logistics distribution vehicle routing problem(VRP)[3] is one of the combinatorial optimization problems, which are very difficult to solve. A common feature of such problems is finding out the optimal solution or near optimal solution under a complex and large solution space. The time to solve the problem will grow exponentially with the problem scale. Due to time constraint, result will loss its feasibility once problem scale becomes very large. To solve such combinatorial optimization problems, people put forward a number of approximate algorithms, such as the shortest path method, the minimum power tree method, fuzzy optimized method[4], the local linear programming and so on. But some of these algorithms lack versatility, because of giving too much attention to the characteristics of individual questions. Based on the similarity of the optimal problem solving way and the annealing process in physical system, and the appropriate use of Metropolis criterion to control the temperature drop in the process, the result can achieve to the global optimization. SA is applicable to a wide range of combinatorial optimization problems. Its global optimal solution has high reliability.

2. SIMULATED ANNEALING ALGORITHM

The simulated annealing algorithm originates from the solid annealing principle; it is a natural optimization process. First of all, the solid is warmed up to a high temperature, then, it is cooled slowly. With the temperature's elevation, the solid's internal particles become disorderly, its internal energy augments. When the solid is cooled slowly, its internal particles become ordered, they goes to an equilibrium state in each temperature. Until the temperature is the normal temperature, they reach to the ground state, and the solid's internal energy reduces to be the least.

How to use the solid annealing principle to simulate the combinatorial optimization problems is necessary to solve. The objective function value can be simulated as internal energy, the controlling parameter does like the temperature. The optimization process begins from the initial solution. With the fall of temperature, the current solution is updated by the iteration process: generate new solution-compute the difference of the objective function-accept or give up the new solution. When the optimization process terminates, the current solution is the approximate optimal solution.

3. EMERGENCY LOGISTICS DISTRIBUTION VRP

When the disaster occurs, the disaster relief control center needs to make out a reasonable material distribution plan in a short time, so that, we should select an efficient algorithm to solve the emergency logistics distribution VRP. This problem deals with a series of stricken spots, select right route, allows the cargo vehicles to pass the stricken spots in order, reaches a certain goal(such as the shortest distance, as little as possible the number of vehicles, etc.) under some constraint conditions

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(such as cargo demand)[5].

What this article discusses actually is a route selection problem, Vehicles' route should be determined in advance. Road network[6] is a complete network, all nodes in the network are connected with each other. The distances among all nodes can be computed out by the nodes' coordinates[7]. The single node's demand is less than the single vehicle's maximum load-carrying capacity. The aim of solving the problem is to find out an optimal route and gain the number of vehicles needed for the relief materials shipping.

3.1 Mathematical description of the emergency logistics distribution vehicle routing problem(VRP)

A road network contains one material center and some stricken spots, it can be represented by a graph G(V,E). V is a set of all nodes. The material center is v_0, $v_0 \in V$. E is a set of all the edge in the graph. The edge between node i and node j is e_{ij}, $e_{ij} \in E$. Because the graph G is a non-direction graph, the edge e_{ij} is a non-direction edge. There are n stricken nodes which ask for relief materials, the relief material demand of the stricken node v_i is q_i. The node serial number of the material center is 0, and the node serial number of the stricken spots is sorted from 1 to n. Every vehicle can not overload materials to the destination, their load-carrying capacity is q, q is larger than $q_i(i=1,2, \cdots,n)$. Based on the mathematical description, every vehicle will be assigned its own route, and the total distance is relatively shorter.

3.2 Mathematical model of the emergency logistics distribution vehicle routing problem(VRP)

Objective function:

$$\min \sum_i \sum_j \sum_k d_{ij} x_{ijk} \tag{1}$$

Constraints:

$$\sum_i g_i y_{ki} \le q \qquad \forall k \tag{2}$$

$$\sum_k y_{ki} = 1 \qquad i = 1,2,3,......,n; \forall k \tag{3}$$

$$\sum_i x_{ijk} = y_{ki} \qquad i, j = 1,2,3,...,n; \forall k \tag{4}$$

where d_{ij} = the distance between node i and node j

x_{ijk}= 1 vehicle k goes from node i to node j

0 else

y_{ki} = 1 vehicle k goes through node i

0 else

In the mathematical model[8], objective function(1) expresses the shortest distance; constraint(2) means that the unloading quantity of any single vehicle should not excess its load-carrying capacity; constraint(3) shows that one stricken spot asks for one vehicle to unload materials; constraint(4) reflects that the vehicle k only goes into the stricken node assigned.

4. THE APPLICATION OF SA IN EMERGENCY LOGISTICS DISTRIBUTION VRP

4.1 The application's mathematical model

The application's mathematical model consists of solution space, objective function and optimal solution. All routes make up the solution space. The vehicle goes back to the material center once it finished its own child route. The total length of all vehicles' route is the value of objective function. The optimal route is the route whose objective function value is the minimum.

4.2 The new route's production and reception mechanism

The process of producing the new route can be described as follows:

Step1: The initial sequence is a sequence which consists of all stricken nodes, every node in the sequence is the only one. According to different random sample design methods, the initial sequence is rearranged, now, the new sequence brings up. Different random sample methods directly effect the production of the new sequence. At present, some popular random sample methods are neighbor node exchange arrangement, random two node exchange arrangement,sub-sequence shifting arrangement, sub-sequence inverted arrangement and so on.

Step2: Node 0 is inserted into the head and tail of the initial sequence and new sequence, it means that the first vehicle starts out from the material center, then, it goes through the stricken nodes of the sequence in order, at the same time, its unloading quantity is accumulated, once the accumulated value will be approximate to the vehicle's load-carrying capacity, the vehicle goes back to the material center, the node 0 is inserted into the sequence, then another vehicle starts its route. Cycling like this, until the entire sequence is traversed. So that, the initial route and new route are produced.

Step3: Using the new route's objective function value to subtract the old route's. If the fronter is less than the later, the new route is superior to the old route, else, the new route is abandoned when it also does not meet the Metropolis criterion.

4.3 The VC implement of the SA algorithm in emergency logistics distribution VRP

Following is the main function of the programme:

```
Simulated-Annealing
{
  //Initializing the temperature
  t0=tCur=InitialTemperature;
  //Initializing the stricken node sequence
  //NowTemp=0;NowInnerIterNum =0
  Route  ReRoute( NowTemp , NowInIter );
  while(tCur>tmin)
  {
    while( NowInIter < MaxInIterNum )
    {
      //Random sample method is adopted
      //New sequence is produced
      Route NewRoute(ReRoute.m_r,NowTemp,NowInIter);
      /* Based on constraints, the material center is inserted
      into the old and new sequence, then, the routes which
      contains  multi-sub routes are produced.*/
      Route  NewRoutePath(NewRoute);
```

```
        Route  ReRoutePath(ReRoute);
        /*compute the distance difference between new route
        and old route*/
        deltaTotalDis=NewRoutePath.m_fTotalDis-
                      ReRoutePath.m_fTotalDis;
        if( deltaTotalDis <= 0.0 )
          ReRoute = NewRoute;
        else
        {
          //Metropolis criterion
          double p = exp( -(deltaTotalDis/NowTemp) );
          int num = rand();
          double random = ((double)( num%10000))/10000.0;
          if(p> random )
            ReRouter = NewRoute;
        }
        NowInIter++;
      }
      tCur=tCur*RecessRatio;
      NowInIter = 0;
    }
}
```

5. SAMULATED SAMPLE

The natural disaster occurs in one area, the material center in this area needs to send the relief materials to twenty stricken spots. One vehicle's load-carrying capacity is eight tons, all vehicles can not overload. The coordinate of the material center is (3.2, 14.1), we can see the coordinates and material demand of those stricken spots in Table1.

node	1	2	3	4	5	6	7
X	3.8	15.2	18.6	11.9	10.2	5.3	0.6
Y	5.5	10.9	12.9	8.2	9.5	9.6	9.9
q	0.8	0.6	0.4	1.6	0.8	1.6	1.9
node	8	9	10	11	12	13	14
X	6.1	7.6	16.0	15.3	1.6	9.0	5.4
Y	15.0	19.2	15.7	15.2	14.7	9.2	13.3
q	1.3	1.8	1.8	0.4	1.6	1.1	1.6
node	17	18	13	19	20		
X	14.5	15.0	9.0	9.8	1.4		
Y	5.3	18.7	9.2	5.0	6.9		
q	1.4	1.2	1.1	0.4	1.4		

Table 1. Stricken spots' coordinates and material demand

Simple temperature control procedure namely weaken cooling procedure is used. Several parameters are initialized as follows: MaxInIterNum=60;InitialTemperature=100;RecessRatio=0.98.
The SA algorithm is an iteration method that relies on the neighborhood structure. How to find out the solution of its neighborhood will directly affect its convergence rate and optimal solution. In this sample, three random sample methods are compared.
M1: Neighbour node exchange arrangement: It means that the random node k in the sequence exchange its position with its neighbour node k+1.
M2: Random two node exchange arrangement: The node k and node j are randomly selected, their positions are exchanged.
M3: Sub-sequence inverted arrangement: The node k and node j are randomly selected, the sequence between them are inverted.
The programmes of three methods are run fifty times separately. See the result in following Table2.

Sample method	M1	M2	M3
AverageLength	147.56206	103.30074	97.8033
AverageTime(s)	30.5968	30.0940	26.0186

Table 2. Average result

Neither in distance nor in time, the third method is superior to other two methods. The shortest length is 97.7437 kilo meters, the programme run 20.0620 seconds. The sub routes of the optimal route are 0-15-13-5-4-17-19-0, 0-12-7-20-1-6-0, and 0-8-9-18-10-11-3-16-2-14-0 in Figure1.

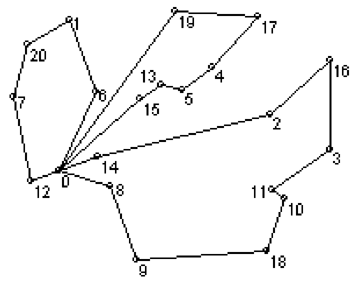

Figure 1. The optimal route

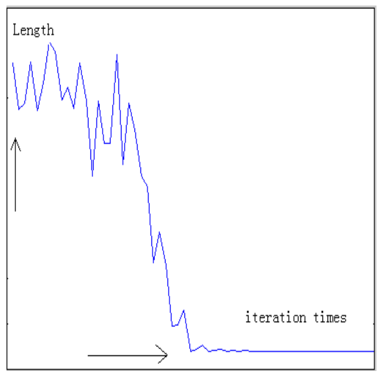

Figure2. The iteration process

The iteration process is simulated in Figure2. The distance value of the current solution fluctuates unceasingly, the phenomenon of stagnation does occur in the SA algorithm's solution computing procedure. It adequately exhibits the SA algorithm's global optimization characteristics.
See from the result above, the SA algorithm is efficient to find out the optimal solution from large solution space. In the procedure, the computation time grows exponentially with the node number. In addition, when the max iteration time is increased, the probability of finding better solution increases.

6. CONCLUSIONS

Recent years, natural disaster, kinds of accident and public disasters erupt frequently. Increasing the efficiency of emergency logistics distribution is very important to the disaster relief work. An efficient optimization algorithm SA is applied to the emergency logistics distribution VRP in this paper. An optimal solution is global optimal in time and distance. In practical application, the road network will be more difficult, a reasonable material distribution plan worked out by the SA algorithm has important guidance significance.

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