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Optimization Algorithm Research of Logistics Distribution Path Based on the Deep Belief Network

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***Abstract*—Aiming at the phenomenon that the urban traffic is complex at present, the optimization algorithm of the traditional logistic distribution path isn't sensitive to the change of road condition without strong application in the actual logistics distribution, the optimization algorithm research of logistics distribution path based on the deep belief network is raised. Firstly, build the traffic forecast model based on the deep belief network, complete the model training and conduct the verification by learning lots of traffic data. On such basis, combine the predicated road condition with the traffic network to build the time-share traffic network, amend the access set and the pheromone variable of ant algorithm in accordance with the time-share traffic network, and raise the optimization algorithm of logistics distribution path based on the traffic forecasting. Finally, verify the superiority and application value of the algorithm in the actual distribution through the optimization algorithm contrast test with other logistics distribution paths.**

Keywords- Deep belief network; Traffic forecast; Logistics distribution; Path optimization

I. INTRODUCTION

With the prosperous development of China's logistics industry, the logistics industry urgently needs the support of the relevant theory and technology. In recent several years, China's cities have had very severe traffic jam, and the logistic distribution path optimization hasn't only involved simple combinatorial optimization. Since the complexity and change of road condition have great impact on the logistic distribution path optimization, and the path passing time would have larger fluctuation in different time ranges, so the road condition change shall be considered upon the research of logistics distribution path optimization. Accordingly, the research of logistics distribution path optimization owns important application value and research significance on the development of logistics industry.

II. RELEVANT RESEARCH

In the 1960s, Ramser et al. raised the path optimization [1] for the first time, and its essence is embodied in the development and change of traveling salesman. The optimization algorithm of logistics distribution path mainly refers to the accurate algorithm in combination with the mathematical theory, including the cutting plane algorithm, branch-and-bound method, Dijkstra algorithm [2-6], etc. Zhang [7] applies the Ant Algorithm, namely, the slope and congestion degree are transferred to the energy to consume the equivalent flat journal so that the route solved is more superior to improve the efficiency for logistics distribution. Chen [8] raises the Ant Algorithm based on the improvement of Pareto. More path optimization algorithms please refer to the literature [9-12].

III. TRAFFIC FORECAST ALGORITHM

A. Traffic Forecast Algorithm DBNTF

In combination with the features of deep belief network technology, in order to solve the accurate prediction of road condition, deep belief network traffic forecast (DBNTF) algorithm is raised. The Flow Chart of algorithm is as follows:

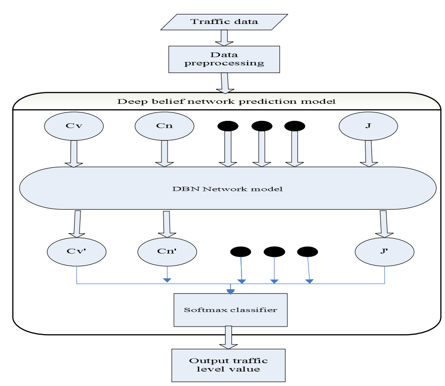

Fig.1. Flow Chart of Traffic Forecast

The Cv, Cn and J indicate the average speed, the vehicle flow and the Holidays and Festivals, respectively. The input vector also includes the weather value, weekend value and other feature data. Cv' and Cn' indicate the feature values after reconstruction.

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B. *Construction and Training of Model*

In consideration of the scale of urban traffic data, the layer number of DBN model is set as the five, and the structure chart is as follows:

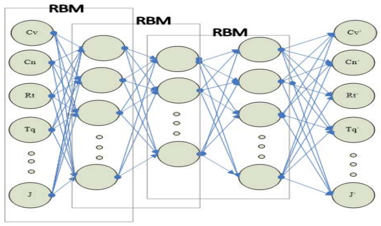

Fig. 2 Structure Chart of DBN Model

The five-layer DBN structure has met the demand for traffic data learning very well, in which, the first layer is the input layer, the last layer is output layer, and the middle layer is the hidden layer. Based on the setting experience of hide layer neuron number for artificial neural network [12], the neuron on the second layer is 2/3 of that on the first layer, the neuron on the third layer is 2/3 of that on the second layer, and the fourth layer and fifth layer are the inversion of the first layer and the second layer.

Finally, the BP (back propagation algorithm) is adopted to slightly adjust the weight parameter. As shown in Figure 3:

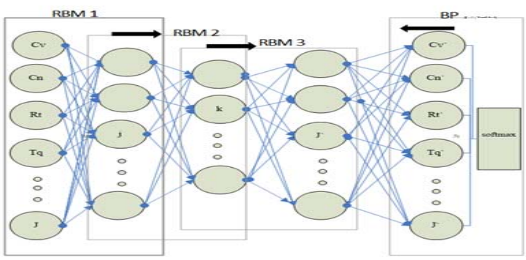

Fig.3 Training of Prediction Model

Firstly, build the training set. The vector V about traffic information characteristics and traffic impact factor would be of new vector X after the learning of DNN model. It is predicted that the model outputs 10 traffic rank values (0-9), in which, the level 0 indicates the failure of passage, the level 9 indicates the rare vehicle at the traffic road section, pass unimpeded. In accordance with the rank value set manually, set the class label y^((i))∈{0,1,2….9} to each vector to indicate ten rank values predicated by the classifier. At this time, the expression of vector set with label is as follows:

$$L=\left\{(x^1,y^1),(x^2,y^2),\cdots,(x^m,y^m)\right\} \tag{1}$$

Then, the predicated classifier is conducted with the solution calculation. The softmax model is promoted by and changed from the logistic regression model in the multi-classification research. The set training collection is input with the label vector set L, the method with usage for more times could be selected. The setting method of hypothesis function is used to evaluate the probability value $p=(y=j|x)$ of each class j. In this way, the hypothesis function $h(x)$ could be expressed as:

$$h_\theta(x^{(i)}) = \begin{bmatrix} p(y^{(i)}=0|x^{(i)};\theta) \\ p(y^{(i)}=1|x^{(i)};\theta) \\ \vdots \\ p(y^{(i)}=9|x^{(i)};\theta) \end{bmatrix} = \frac{1}{\sum_{j=1}^{10} e^{\theta_j^T x(i)}} \begin{bmatrix} e^{\theta_1^T x(i)} \\ e^{\theta_2^T x(i)} \\ \vdots \\ e^{\theta_9^T x(i)} \end{bmatrix} \tag{2}$$

The θ in the above formula indicates the parameter value of classifier needing to be calculated. In this way, only the cost function shall be set, work out the parameter θ_k after iteration by selecting the classifier model parameter with the minimum iteration, thus obtaining the final prediction classifier. Cost function $j(\theta)$:

$$j(\theta) = -\frac{1}{m}\left[\sum_{i=1}^{m}\sum_{j=1}^{k}\left\{y^i = j\right\}\log\frac{e^{\theta_j^T x(i)}}{\sum_{j=1}^{k} e^{\theta_j^T x(i)}}\right] \tag{3}$$

$y^{(i)}$indicates the output Eigenvector with the traffic rank value of 10, the kth 1 (not 0) indicates the traffic rank value of K-1, for example, the $y^{(i)}=[0,0,0,0,0,1,0,0,0,0]^T$ indicates the traffic rank value is 5, and the traffic isn't blocked and smooth in such time period. The traffic rank value Y indicates the traffic capacity, the value Y is the label data of DBNTF algorithm upon supervision and training, and the solution formula of value Y is as follows:

$$Y = \frac{v_t}{v_{\max}}\left(1-\frac{Cn}{Cn_{\max}}\right)9\varphi \tag{4}$$

In the above formula, the v_t, v_{max}, Cn, $Cn_{max}$and φ indicate the average speed at the current time period, the limit speed of road, the traffic flow within such time period, the peak value of traffic flow, and the adjustable parameter of rank value. It is more accurate to reflect the traffic ability of road section based on the speed and traffic flow.

IV. Path Optimization Algorithm Based on Traffic Forecast

A. *Time-share Traffic Network*

The expression of time-share weight W_L^tcould be defined as follows:

$$W_L^t = S \times \frac{c}{Y^t} \tag{5}$$

B. *Improvement of Ant Algorithm*

Substitute the formula (6) and (7) into the formula (8) of the moving probability, to obtain the following formula (9) that ant moves from one intersection node to another intersection node:

$$\eta_{ij} = \frac{1}{d_{ij} w_t} \tag{6}$$

$$d_{ij}^t = sw_i^t \tag{7}$$

$$p_{ij}^k(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^\alpha \bullet [\eta_{ij}]^\beta}{\sum_{allowed_k} [\tau_{ij}(t)]^\alpha \bullet [\eta_{ij}]^\beta}, j \in allowed \\ 0, otherwise \end{cases} \tag{8}$$

$allowed_k$={1,2,…,n-1}indicates that the ant k can access the delivery point in the next step. η_{ij} denotes the degree of expectation, α denotes the pheromone accumulated in the movement, and β denotes the different influence of the heuristic factor in the path selection. During the access process, the pheromone will continue to decay until it disappears. The pheromone disappears with the parameter 1−ρ, and the pheromone on the line is updated after the ant algorithm accesses the distribution point (with time n).

$$p_{ij}^k(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^\alpha \bullet [s \bullet w_L^t]^{-2\beta}}{\sum_{allowed_k} [\tau_{ij}(t)]^\alpha \bullet [s \bullet w_L^t]^{-2\beta}}, j \in allowed \\ 0, otherwise \end{cases} \tag{9}$$

The variable quantity of pheromone is Q/Z, the total length Z of path could be obtained by the summation of formula (7). By combination with the formula (10) and (11), the updating formula of pheromone could be worked out:

$$\tau_{ij}(t+n) = \rho\tau_{ij}(t) + \Delta\tau_{ij} \tag{10}$$

Indicates that the pheromone on the line should be updated after the ant algorithm accesses the delivery point once (with time n).

$$\Delta\tau_{ij} = \sum_{k=1}^m \Delta\tau_{ij}^k \tag{11}$$

In the formula, $\Delta\tau_{ij}^k$ denotes the pheromone left by the kth ant between distribution point's ij in this iteration, which reflects the size of the path length, and $\Delta\tau_{ij}^k$ denotes the m between distribution points ij in this iteration. The amount of information left by only the ants.

$$\tau_{ij}(t+n) = \rho\tau_{ij}(t) + \sum_{k=1}^m \frac{Q}{d_{ij}^t} \tag{12}$$

Through the above improvements, in the time-division traffic network, the following improved ant path optimization algorithm（IAPOA） is as follows:

Algorithm 1: Improved ant path optimization algorithm
Input: Accessible node set {Rn}, delivery point [p]
Output: Optimal path S

Step1: The initialization time T = 0, the number of cycles N_c = 0, set the maximum number of cycles, put m ants randomly to n distribution points, the initial pheromone of all the road segments is constant C, pheromone update $\Delta\tau_{ij}^k$ is 0, the initial Junction nodes are placed in a Taboo table;

Step2: Get the current intersection accessible node set {Rn} from the traffic network, move to the next intersection node according to formula (11) and {Rn};

Step3: Update the Taboo table and move the intersection node to the taboo table in step 2;

Step4: Cycle through step 2 and step3. When the ant stops moving, the iteration ends;

Step5: Calculate the weight and W_a of each ant's walking route that successfully visits all delivery points, and update the pheromone and optimal path S according to the formula (7).

C. Path Optimization Algorithm DBNTFPO

The optimization algorithm of logistics distribution path based on DBNTF is referred to as the algorithm of DBNTFPO (Deep belief network traffic forecast path optimization).

Algorithm 2: DBNTFPO Algorithm
Inputs: traffic feature data [D], traffic network logistics structure [N]; distribution time t, and distribution site n
Output: time-share weighted traffic network [N']; distribution route S

(1) Construction of time-share traffic network
(i) The traffic feature data [D] is input as the algorithm 3-3 (DBNTF algorithm), and the time-share traffic rank value Y^t is obtained;
(ii) Substitute the time-share traffic rank value Y^t into the formula (5), and the time-share weight W^τ_L of road section is obtained;
(iii) The weight of logical structure [N] is set in accordance with the road section time-share weight W^τ_L ;
(iv) Output the time-share weighted traffic network [N'].
(2) Solution of distribution route
(v) Conduct the [N'] initialization to the time-share weight traffic network in accordance with the distribution time t, namely, solve the initial weight W^τ of road section in network;
(vi) Put m ants into n distribution points to conduct the solution through the algorithm 1;
(vii)Output the optimal route S.

V. TEST RESULTS AND ANALYSES

A. Example Introduction

There is a logistics delivery company at Nanning railway station, which delivers certain goods to 30 distribution points. The distribution period is from 7:00 am to 7:00 pm, and their specific locations are shown in the following figure 4:

B. Experiment Results and Analyses

In order to verify the effect of the algorithm in this paper, three vehicles of distributing certain goods select the route in different methods, and the three methods are as follows:

The quantity and the average road section number of the distribution route within one week are shown in Table 1:

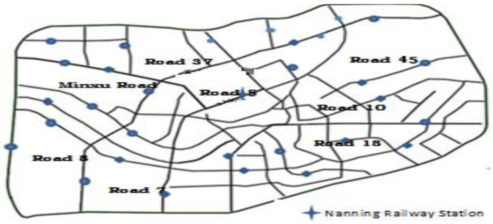

Fig.4 Distribution point circuit diagram

Table 1 Quantity of Various Method Solutions within One Week

Algorithm	The number of solutions	Average number of road sections
Ant algorithm	1	189
Driver Experience	25	172
DBNTFPO algorithm	59	175

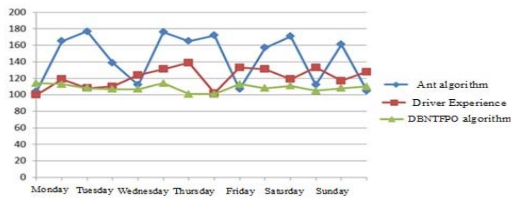

Fig.5 Distribution Time Figure in Three Methods

The distribution time data are recorded and collected by the distribution driver. Based on Figure 5, the algorithm in such paper has a relatively obvious time advantage, and the distribution time is relatively stable. Traditional Ant Algorithm includes the single route, and has larger change and fluctuation in time, with poor anti-risk capability. The distribution time is also unstable in the driver experience method, because the drivers mainly select the path according to individual experience, with the relatively stable distribution, but the path isn't the optimal.

Table 2 Average Schedule

Ant algorithm	144.5
Driver Experience	121.0
DBNTFPO algorithm	108.5

Based on Table 2, the traditional Ant Algorithm has been not suitable for the route optimization problem under the complex road condition, and the algorithm in this paper could effectively reduce the distribution time compared with the distribution experience of driver. In the actual logistics distribution, the algorithm in this paper has good applicability and effectiveness.

VI. Conclusion

The innovation point of this paper is to introduce deep learning method to the route optimization. Most traditional route optimization algorithms are the simulation theories, which disjoint with the actual condition. Lots of traffic data are learned in the deep learning method, the feature factor of road condition is extracted, and the road condition is predicated accurately by combination with the classifier. The paper solves the weak actual application of traditional algorithm, and provides a kind of new thought for solving the logistics distribution path optimization problem.

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