The Method of Restricted Searching Area Optimal Route Guidance Based on Parallel Genetic Algorithm and Neural Network*

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Abstract: To work out route guidance in gigantic traffic network, the traffic information forecasting method based on Artificial Neural Network is studied in-depth and the time-varied road weight matrixes are constructed, which solve the problem of limitation in traditional and static road weight. The Parallel Genetic Algorithm (PGA) for optimal route choice is discussed in this paper and the corresponding genetic operator, mutation operator and the refresh way of the populations are also proposed. A method of Rectangle Restricted Searching Area (RRSA) which can reduce the searching area of PGA is presented. The problem of bad real-time and astringency of PGA existed in computing the optimal route in gigantic traffic network has also been solved using RRSA. To probe into the technology of the Route Guidance, a large number of experiments combined with the required analysis of the results have been carried on. It is indicated by simulation that the presented method of optimal route choice has achieved the accuracy, real-time and quick guidance in gigantic traffic network.

Key words: neural network; road weight matrix; rectangle restricted searching area; parallel genetic algorithm; optimal route choice

0 Introduction

In Intelligent Transport Route Guidance System, to find out the optimal route from gigantic road network effectively and quickly has been an ideal case. The traditional Dijkstra algorithm is easy to operate and able to compute the shortest oute with 100 percent[1]. However, the node's locations are ignored and the shortest route is searched from all the directions, moreover, the Dijkstra algorithm may be inefficient when the road network includes lots of nodes[2]. Recently, many researchers have focused on solving the optimal problems with the method of artificial intelligence, neural network, fuzzy system and the late proposed methods such as simulated annealing algorithm, Tabu searching method and genetic algorithm, and many good applications have already been achieved[3]. Zou, et al have used the GA to calculate the shortest route of the dynamitic network and produced the initial population using the random Dijkstra algorithm, with which the time complexity of GA is decreased[4]. Zhu, et al have proposed the optimal route method based on improved GA in which the chromosome is operated before the normal gene, as a result, the searching time is reduced in non-initial optimal answer[5]. The researches mentioned above are almost made on medium-sized and small road network, however, for complicated gigantic traffic network, the amount and time complexity of GA will be increased greatly and the performance of convergence will be degraded or it will takes on the non-convergent state. According the spatial distribution characteristic of traffic network, a new optimal route method based on restricted searching area, parallel GA and neural network is presented in this paper, which can reduce the searching area, enhance the operating efficiency and improve the low efficiency of GA for seeking the optimal route in gigantic network.

1 The optimal route algorithm based on restricted area

1.1 Travel time prediction based on artificial neural network (ANN)

The traffic flow has the characteristic of uncertainty and complexity. As Wahle comments that the road weight constructed by traditional method is almost static and certainty, and can't describe the time-varied traffic network[6]. ANN is an effective data modeling method and has the characteristics of nonlinear, flexibility and integration. It can make real-time predication of traffic information accurately and effectively, thus the time - varied road weight matrix can be

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constructed[7]. The ANN travel time predication model consists of data processor and the ANN. Data processor is mainly used to handle the actual sampling travel time and traffic flow, and then turn them into the input pattern which can be used in ANN. ANN includes input layer, hidden layer and output layer.

In travel time predication, the traffic flow vector of road i at time τ and $\tau-1$ are denoted by $q_i(\tau)$ and $q_i(\tau-1)$ respectively. Traffic flow vector of the whole road network at time τ is expressed as $Q_i(\tau)=[q_1(\tau), q_2(\tau), \cdots, q_d(\tau)]$, where d is the total road number of the traffic network, if only one road's traffic flow is considered, then $d=1$. Correspondingly, we assume that the travel time vector of road i at time τ and $\tau-1$ are denoted by $t_i(\tau)$ and $t_i(\tau-1)$ respectively, travel time vector of road network at time τ is denoted by $T_i(\tau)=[t_1(\tau), t_2(\tau), \cdots, t_d(\tau)]$.

Considering the roads' length and traffic flow characteristic, traffic flow and travel time of road network at time, $\tau, \tau-1, \tau-2, \tau-3, \cdots, \tau-m$ are used to predicate the travel time at time $\tau+1$. So $Q_i(\tau), Q_i(\tau-1), \cdots, Q_i(\tau-m)$ and $T_i(\tau), T_i(\tau-1), \cdots, T_i(\tau-m)$ are used as the inputs, $T_i(\tau+1)$ and is being the output of ANN.

1.2 Rectangle restricted searching area algorithm

Rectangle restricted searching area algorithm proposed by Lu F. is an improvement of the ellipse restricted searching area algorithm, and can solve the problem of finding the optimal route ineffectively in gigantic road network[8]. According to the features of road network, for each pair of starting point and goal point there must be a corresponding limit distance between them. Taking starting point and goal point as the foci and the limit distance between them as the long axis, an ellipse is bounded. Correspondingly, the rectangle, which is the finial searching area, can also be bounded through the ellipse. After bounding the rectangle, each node of the road network should be judged and decided whether it is within or out of the rectangle area. The method can restrict the searching in certain area and reduce the computational complexity and searching size of GA. The rectangle restricted searching area algorithm is described as follows.

Assuming $S(X_S, Y_S)$, $N(X_N, Y_N)$ be the coordinates of the starting points and goal points, and let S and N be the foci, so the ellipse equation can be written as:

$$\frac{[\cos\theta(x-a)+\sin\theta(y-b)]^2}{A^2}+\frac{[-\sin\theta(x-a)+\cos\theta(y-b)]^2}{B^2}=1, \quad (1)$$

where θ, a, b, A and B are denoted by:

$$\theta=\operatorname{arctg}\left(\frac{Y_N-Y_S}{X_N-X_S}\right), \quad (2)$$

$$a=\frac{X_S+X_N}{2}, b=\frac{Y_S+Y_N}{2}, \quad (3)$$

$$A=\frac{\tau}{2}\sqrt{(Y_N-Y_S)^2+(X_N-X_S)^2}, \quad (4)$$

$$B=\sqrt{A^2-\frac{(Y_N-Y_S)^2-(X_N-X_S)^2}{4}}, \quad (5)$$

τ is the scale factor, which can infect the size of searching area, and obtained through the city road network sample data after statistical calculation. To calculate the partial derivative of (1), then the extreme value of x and y can be written as:

$$X_{\max}=a+\sqrt{A^2\cos^2\theta+B^2\sin^2\theta}, \quad (6)$$

$$X_{\min}=a-\sqrt{A^2\cos^2\theta+B^2\sin^2\theta}, \quad (7)$$

$$Y_{\max}=b+\sqrt{A^2\sin^2\theta+B^2\cos^2\theta}, \quad (8)$$

$$Y_{\min}=\sqrt{A^2\sin^2\theta+B^2\cos^2\theta}, \quad (9)$$

let $X_{\max}$, $X_{\min}$, $Y_{\max}$ and $Y_{\min}$ be the rectangle's four vertexes, the rectangle is bounded.

The graphic primitives of road are saved as single point one by one, however, a road has two points at least, i.e, starting point and goal point, so the discrimination of a road within or beyond the rectangle area must be judged from the nodes. The discrimination rules are described as follows.

Starting point and goal point should be judged firstly. If one of them lies in the rectangle area, the road is within the area. If neither of them lies in the area, the following computation must be done. Firstly, finding the center point of the rectangle area, computing the length of the rectangle diagonal and obtaining the middle points of the road; secondly, comparing a half length of rectangle's diagonal and the distance between the road's middle points and the rectangle's center point; finally, making judgment that if the latter greater than the former, the road is beyond the area, otherwise, it is within the area. After the judgment the nodes within the rectangle will be searched by the optimal route algorithm.

1.3 Optimal route selection using parallel genetic algorithm

Optimal route selection method based on Parallel Genetic Algorithm (PGA) is described as follows:

Step 1: Chromosomal coding: The order real number is used to code the chromosome. Each gene of the chromosome represents a node number in the road network. The chromosome length equals to the number of nodes within the restricted area.

Step 2: Fitness function: Two fitness functions are proposed here. One is used in the earlier stage of the PGA computation and denoted by:

$$f(k) = p(k)/(1 + p_{\max}), \tag{10}$$

where $k = 1, 2, 3, \cdots, M$, M is the size of population, and p is the effective gene fragment, represents that in chromosome there are p adjacent nodes which are connected by roads in real road network. $p(k)$ is the effective gene fragment of kth chromosome, $p_{\max}$ is the maximal number of the effective gene fragment in the current generation.

When PGA computing is up to certain generation, the other fitness function is used and denoted as:

$$f(k) = 1 - P(k)/\sum_{1}^{k} P(k), \tag{11}$$

where $P = \sum d(i,j)$ and $d(i,j)$ is the travel time from the ith nodes to the jth nodes.

Step 3: Chromosomal crossingr: After selecting two parent chromosomes at probability P_c, select a cross point Q, except the starting point and the goal point, from the parent chromosome A and B at random, so Q should be selected from the third node at least. In crossing operation, the following rules must be kept:

Firstly, if, $\max(p_A, p_B) \geqslant \min(z_A, z_B)$, where p is the effective gene fragment and z is the number of nonzero genes, the parents can't make cross operation, so the cross won't happened in the effective gene fragments and the zero genes.

Secondly, if $\max(p_A, p_B) \leqslant \min(z_A, z_B)$, Q should be chosen between the $\max(p_A, p_b)$ and $\min(z_A, z_B)$, so the parents' effective gene fragments won't be damaged; then, let the redundant nodes and the repetitious nodes of the two new crossed chromosomes be removed and the end of the two chromosomes be filled with zeros for not changing the chromosome length.

Step 4: Chromosomal mutation: Select one parent chromosome at probability P_c. In the selected chromosome, if the first gene of non-effective fragment is not the ending point, let it be mutated, otherwise, insert a node before the ending point, which has to follow the coding rules and keep the length of the chromosome. After mutation, if the effective gene fragment of the new chromosome is longer than that of the old one, which means that the value of p is increasing, let the new one substitute for the old one, otherwise, keep the old one.

Step 5: Chromosomal selection: The optimal survival strategy and roulette method are combined to make the selection operation. The new generation is obtained by operations of roulette, crossing and mutation in the old one. In initial generations of PGA, the individual who has less effective gene fragments in new generation is substituted by the one who is reasonable in old generation which means each gene is connected to other genes who next to it. If no reasonable individual, no substitution should be done. In the latter generations of PGA computing, if the fitness of the best individual in old generation is better than that of the worst individual in new generation, substitute the worst individual of the new generation by the best one of the old generation. If the best individual of the old generation is unreasonable, no substitutions should be done either.

Step 6: group updating: In PGA computing, two populations are proposed here. After several generations computing, the best individuals in one population should be emigrated to the other population by one to one ways. Then the new populaions are constructed.

2 Simulation results

The experiment is carried out based on a city traffic network in Shenyang. The experiment network includes 74 nodes. Let the travel time be the minimum object to search the optimal route.

Firstly, predicate the travel time of the road network at time m using ANN. Travel time and traffic flow at time $m-1$、$m-2$、$m-3$、$m-4$、$m-5$ are taken as the input of ANN, and each road's average travel time at time m as the output. The ANN model consists of 10 neurons in input layer, 1 neuron in output layer and 4 neurons in hidden layer determined by experiments. The road weigh matrix contains 74×74 data, as shown in Table 1. In Table 1, these numbers in the first row and the first column represent the nodes in the road network and the element in the ith row and the jth column represents the travel time from node i to node j. If there is no connected road between node i to node j, the number '1 000', which is bigger than the sum of all roads' travel time, is used to represents the travel time.

Tab.1 Average travel time of road network at time m (minutes)

Road Network Nodes	1	2	3	…	72	73	74
1	0	2.1	1 000	…	1 000	1 000	1 000
2	2.5	0	1.48	…	1 000	1 000	1 000
3	1 000	1.6	0	…	1 000	1 000	1 000
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
72	1 000	1 000	1 000	…	0	3.71	1 000
73	1 000	1 000	1 000	…	4.25	0	2.2
74	1 000	1 000	1 000	…	1 000	2.65	0

Secondly, obtain the rectangle area using rectangle restricted searching area method. Generate the starting point and the goal point, decide the scale factor $\tau = 1.93$ through statistical calculation of the sampled data from the city road network, judge which nodes are within the area, then an optimal route can be find in these nodes. The rectangle area is shown in Figure1.

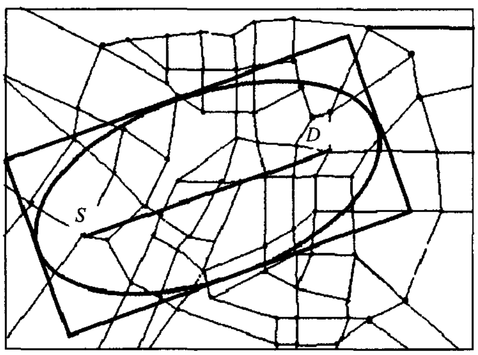

Fig.1 Rectangle restricted searching area

Thirdly, find the optimal route at time m between two designated nodes using PGA method. The parameters of PGA are determined as follows: the coding length of te chromosome equals to the number of nodes within the restricted area; subpopulation's number is 2 and size is 100; the mutation rate $P_m = 0.6$, the crossing rate $P_c = 0.4$ and the migration rate is 0.5; the terminal generation is 15. The transfer interval should be determined by experiments because it influences the performance of GPA directly.

When the transfer interval T is 8, the average running time of PGA is 11.5 s. The average fitness of two populations has obvious difference due to the little transfer times, little communications between them and good individuals are not transferred in time. When the transfer interval T decreases to 3, good individuals transfer frequently. The communication time increases. PGA' running time increases obviously and gets up to 24.2 s. Due to the small transfer interval, good individuals' spread and the convergence speed are fast, subpopulations' diversity decreases and PGA is easy to converge to the minimum point of part area. When the transfer interval T is 5, the average running time of PGA is 13.3 s. The solution efficiency of PGA is not affected with the increased communication time. The good individuals can contribute to increase the populations' fitness, keep up the populations' diversity and converge to the optimal solution. So the transfer interval T is taken to 5 through experiments. The curves of two subpopulations' fitness is shown in Figure 2, Figure 3, and Figure 4, where the abscissa axis represents the PGA generations and the ordinate axis represents the average fitness value of the subpopulations.

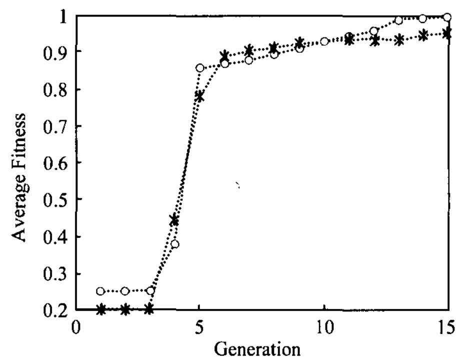

Fig.2 The varying curves of two subpopulations' average fitness when $T = 8$

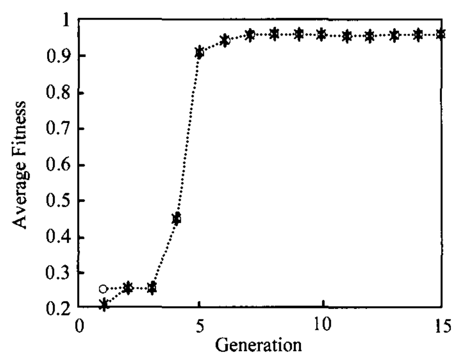

Fig.3 The varying curves of two populations' average fitness when $T = 3$

In order to solve the optimal route of arbitrary origin and destination (OD), lots of simulations using PGA and restricted area PGA methods by MATLAB have been done. The results are shown in Table 2, where M is the size of subpopulations, *String-length* is the length of chromosome, *Send-rate* is the transfer rate, *Send-interval* is the transfer interval, $\overline{T}$ is the average spending time of GA for computing an effective or optimal route, *Accuracy* is the accurate ratio of

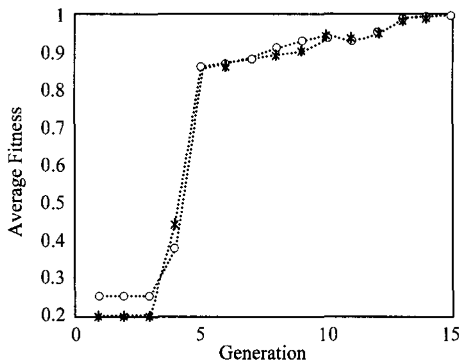

Fig.4 The varying curves of two populations' average fitness when $T = 5$

optimal route solutions, which equals to the ratio between the optimal route OD pairs number and the OD pairs number included in the road network, and *Effectiveness* is the effective ratio, which equals to the ratio between the effective route OD pairs number and the OD pairs number included in the road network.

Tab.2 The results of the optimal routes using PGA and restricted area PGA

Methods	M	*String-length*	*Send-rate*	*Send-interval*	$\overline{T}$ (s)	*Accuracy*	*Effectiveness*
PGA	200	74	0.5	5	45 ~ 75	0.994	1
RPGA	200	2 ~ 60	0.5	5	10 ~ 25	0.990	0.995

The simulation results show that the restricted searching area optimal route method based on PGA can find out the optimal route effectively and quickly. Because the restriction of the rectangle, the effectiveness of this optimal method can not be up to 100 percent, but the coding length of the chromosome is shortened, the crossing and the mutation operations are reduced greatly, and the convergence speed of PGA is improved. So the optimal method proposed here can meet the real-time requirement of route guidance system and improve the PGA's computing ability in gigantic road network.

3 Conclusion

In this paper the travel time of the roads is predicated by ANN, which solved the problem of limitation of the traditional static road guidance method . The searching size of PGA is reduced, the convergence is accelerated, and the efficiency of solution is also enhanced by using the rectangle restricted searching area algorithm, which improves the performance of PGA for real time route guidance in gigantic road network. It has been proved experimentally that the rectangle restricted searching area optimal route method, based on PGA and ANN, has the characteristics of good real-time and high efficiency.

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