

## Research on Real-Time Optimal Path Algorithm of Urban Transport

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### Abstract

Based on the ant colony algorithm, urban real-time traffic optimal path algorithm was designed through restricting search area and search direction of ant colony system, making the real-time traffic and distance as the optimal path weights and regarding intersection turning as the impact of weight value combined with Chinese situation. The algorithm could calculate the optimal path through algorithm complexity test. We obtained a traffic optimal path with timeliness and practical value combined with ant colony algorithm considering multiple parameters. The obtained path enabled user to reach destination within a short time and with the least fuel through actual traffic test. It was regarded as the optimal path.

**Keywords:** intelligent transportation, the optimal path, real-time traffic, ant colony algorithm

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### 1. Introduction

The daily number of registered vehicle has grown more than 800 vehicles in Zhengzhou in 2012. The city owned 2 million vehicles till August 2012. Car users are faced with great difficulty [1] by considering the current status.

Except accelerating urban road construction, path guidance and optimization is another necessary way to solve traffic problems and help car users get to their destinations conveniently. Dijkstra algorithm [2], A\* algorithm, genetic algorithm and ant colony algorithm [3], etc are common path optimization algorithms [4]. They are simulated under static path conditions and the weight value considered is only the length of the path. Except distance, path parameters are affected by real-time traffic [3] and intersection turning number in urban traffic. Turning limitations, turning time and the delay time can reach 17%-35% of total time.

A problem need to be solved is how to combine the three parameters: real-time traffic, distance and intersection. Since each path has its corresponding real-time traffic, we can regard each part of real-time traffic as a part of the weight values and each intersection turning is represented by parameters [5-8], then we can obtain a traffic optimal path with timeliness and practical value in combination with ant colony algorithm [9] and through consider the multiple parameters affecting vehicle so as.

### 2. The Establishment of Road Network Model

#### 2.1. The Establishment of Urban Roads Model

The complex urban road traffic network makes the structure of topological relation network diagram. Plane intersection will be the analysis object of system. The urban traffic network is analyzed to plane intersection as split point, then the road traffic network has become point and line topology network structure. The structure represents a plane intersection as a point and a road as a line. The whole network model can be described through graph  $G = (V, D, W, A)$  as is shown in Figure 1.  $V$  is the set of urban road nodes;  $D$  is the weight values from node  $V_i$  to  $V_j$ .  $W$  indicates the delay time when passing node  $V_j$  from  $V_i$  to  $V_k$ . The parameter has directivity.  $A$  stands for road line segments and has directivity.

The road traffic direction and city road network model of the intersection was built. The problem for real-time path is equaled to find the smallest weight values between two nodes in the diagram  $G(V, D, W, A)$ , which simplifies the solving process of path.

## 2.2. Speed-flow Model Selection

This speed-flow model is consistent with the United States BPR function and speed-flow model suited for China traffic is obtained from Chinese Ministry Transportation project named "Highway Capacity research", such as Equation (1).

$$V = \frac{\alpha_1 V_0}{1 + (U / C)^\beta}, \beta = \alpha_2 + \alpha_3 (U / C)^3 \quad (1)$$

In Equation (1),  $V$  is actual speed, and  $V_0$  is standard speed.  $U$  is the actual vehicles and  $C$  is the maximum vehicles withstand by road.  $\alpha_1, \alpha_2, \alpha_3$  is the regression parameter whose value varies with different road grade. Assuming  $L$  is the road length, and road travel time can be show in Equation (2):

$$T = \frac{L}{V} = \frac{L + L(U / C)^\beta}{\alpha_1 V_0} \quad (2)$$

We should update real-time traffic flow  $U$  in  $\Delta t$ . The  $\Delta t$  can differ according to actual situation. Generally, the value is 10min. Road network is refreshed once  $\Delta t$  which can keep system out of continuous refreshing state and ensure a small error. Combined with ant colony algorithm, it was adopted to study on urban real-time traffic optimal path.

## 2.3. Intersection Delay Model Design

Before each sections downstream intersection ago, the vehicle lined up in the downstream sections of columns and extends back constantly when the light turns red. The vehicle queue length decreases constantly when the red light turned off. This is called scattered wave formation and disappearance. Setting the speed of vehicle queue length change is faster than wave speed back the light turns green, namely the queue can completely disappear.

The analysis of queue vehicles dissipate rate in the intersection (by the jam to flow) shows that the delay is related to number of queuing vehicle and queue dissipation rate. Queue dissipation rate is the intersection capacity  $C(t)$  when intersection is congested. The rate is inflow rate of traffic if there is no queuing.

Assuming downstream intersection on Red time  $r$ , the number of queuing vehicles at time  $t$  sections  $\langle V_i, V_j \rangle$  is  $N$  and the traffic speed on the road  $\langle V_i, V_j \rangle$  at time  $t$  is the flow  $V$ , we can get intersection delay within the time interval  $\Delta t$ . The result is shown in Equation (3):

$$w(t) = \frac{Q(t)}{C(t)} = \frac{r \cdot V(t) + r \cdot V(t + \Delta t)}{2C} \quad (3)$$

## 3. The Optimal Path Based on Improved Ant Colony Algorithm

### 3.1. Algorithm Model-building

The more ants pass on a path and it can affect choice of other ants. An optimal path is formed through iterative. The ant colony algorithm is robust and easy to parameters. The path is determined through weight, including distance, real-time traffic and delay.

Assuming there are  $m$  ants at starting point. The path is  $\langle V_i, V_j \rangle$ . Weight is  $d$ .  $\tau$  is pheromone on the path.  $\eta$  is path visibility or expectations to choose  $\langle V_i, V_j \rangle$  with a value of  $1 / d_{ij}$ . Allowed $_k$  is the next selected set of nodes.  $\alpha$  is stimulating pheromone factor.  $\beta$  is desired inspiration factor. Then ants choose a path to  $V_j$ . The probability can be shown in Equation (4).

$$p_{ij} = \begin{cases} \frac{[\tau_{ij}]^\alpha [\eta_{ij}]^\beta}{\sum_{j \in allowed_k} [\tau_{ij}]^\alpha [\eta_{ij}]^\beta} & j \in allowed_k \\ 0 & else \end{cases} \quad (4)$$

This path pheromone will be updated after an ant chooses a path. It can be shown in Equation (5).

$$\tau_{ij}(t + 1) = (1 - \rho) \times \tau_{ij}(t) + \sum_{r=1}^f \Delta \tau_{ij}^r, (\Delta \tau_{ij} = \frac{Q}{d_{ij}}) \tag{5}$$

In Equation (5), t is number of iterations,  $\rho$  is pheromone evaporation coefficient.  $\tau_{ij}(t+1)$  represents pheromone changes in next iteration on  $\langle v_i, v_j \rangle$ .  $\Delta \tau_{ij}$  is increased pheromone when ants choose  $\langle v_i, v_j \rangle$ . Q is the quality factor of pheromone, which is a constant, often taken 1.

Optimal network path is obtained by combining the actual model road network and improving the basic ant colony algorithm.

**3.2. Optimization of Timeliness**

If we consider the whole city nodes, it will need a long computation time. In real driving situation, they are limited to some areas under real factors such as time, fuel consumption and traffic. Ant colony algorithm can be simplified if the reasonable search of a range of area can be selected.

Selection of search area is shown in Figure 2. The rectangular I is formed based on diagonal rectangle of start and end. The rectangle can be used as the smallest area to calculate optimal path, but we should be magnified the search area because of the restrictions in real traffic. Extending the diagonal for outer of start and end points to take intersect nodes, we should scale out 1-2 nodes on the diagonal of rectangle I. The search area is enlarged from rectangular I to rectangular II.

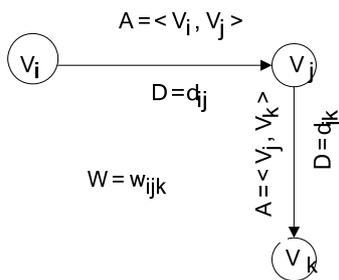


Figure 1 directed weighted graph

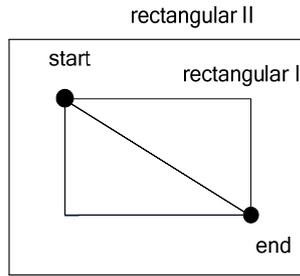


Figure 2 rectangular bounding

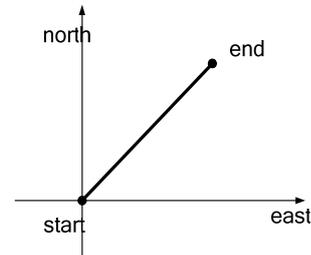


Figure 3 vector diagram

A vector is formed from beginning to end, as is shown in Figure 3. Algorithm computing speed can be accelerated and the complexity can be reduced through making the search direction almost accord with vector during the process.

Value of  $\eta_{ij}$  controls direction.  $\eta_{ij}$  represents expectations that ants choose the path  $\langle v_i, v_j \rangle$ . The parametric  $d_{je}$ ,  $d_{je}$  represents linear distance from  $v_j$  to target point, and parameters  $d_{je}$  aims to strengthen the search direction.  $\lambda_1$  and  $\lambda_2$  represent the scale factor. It can be shown in Equation (6).

$$\eta_{ij} = 1 / d_{ij} = \frac{1}{\lambda_1 d_{ij} + \lambda_2 d_{je}}, (\lambda_1 + \lambda_2 = 1) \tag{6}$$

Ant colony algorithm is restricted from search area and direction, and the complexity of the algorithm is greatly reduced. It will be proved by following instances.

**3.3. Obtainment of the Optimal Path Weight**

The optimal path in system is based on time, namely the optimal path is the path which takes the shortest time. In order to make the calculation of the optimal path timely, real-time

Speed-flow and intersection delay time should be regarded as parts of the weight value. Namely, the model of value is established through these two factors.

Assuming the path length is L. S is the average vehicle length, r represents red light time of intersection. The results are shown in Equation (7).

$$\Delta\tau_{ij} = \frac{2QCV(t)}{2LC - [V(t) + V(t + \Delta t)][CS - V(t)]r} \tag{7}$$

$$\eta_{ij} = \frac{2CV(t)}{\lambda_1\{2LC - [V(t) + V(t + \Delta t)][CS - V(t)]r\} + 2\lambda_2 CV(t)d_{je}}, (\lambda_1 + \lambda_2 = 1) \tag{8}$$

When ant colony algorithm values change,  $\eta_{ij}$  and  $\Delta\tau_{ij}$  will change. Then value of  $p_{ij}$  is affected, and finally we should select the optimal path.

#### 4. Application Experiment

The timeliness and effectiveness based on improved ant colony algorithm is verified by an example, taking part in Zhengzhou City. The map is shown in Figure 4.



Figure 4 part of Zhengzhou city traffic map

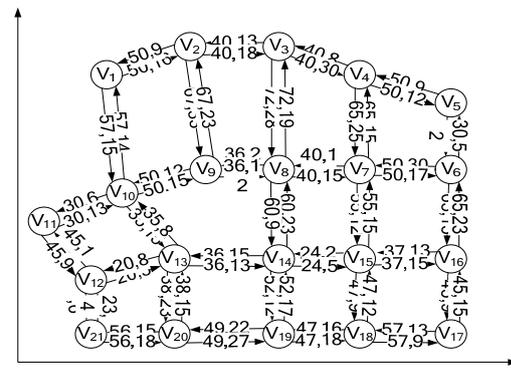


Figure 5 road network model diagram

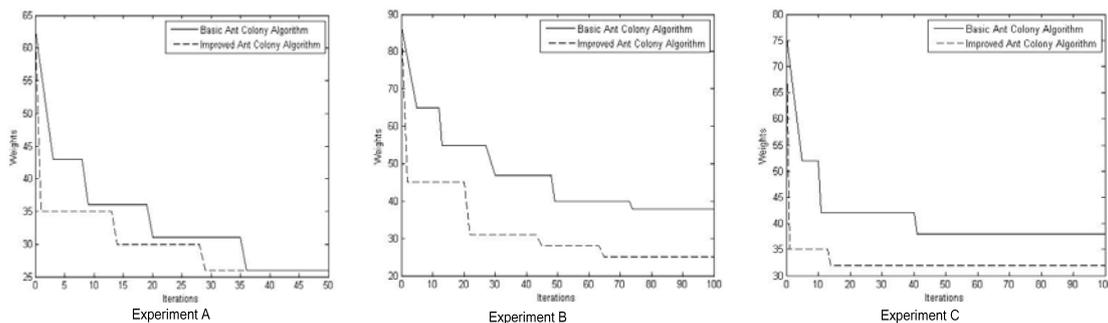


Figure 6 the comparison in the convergence rate

The map is abstracted as a network model diagram with weight. There are 21 nodes in the diagram and the flow of paths is measured shown in Figure 5. Direction of the arrow is pointed from  $v_i$  to  $v_j$ . Times of each intersection traffic lights have been tested to obtain the data in advance. If steering is prohibited, the time of traffic lights is infinite ( $\infty$ ).

We take  $\alpha = 1$ ,  $\beta = 2$ ,  $Q = 1$ ,  $\lambda_1 = 0.4$ ,  $\lambda_2 = 0.3$ ,  $\lambda_3 = 0.3$ ,  $\alpha_1 = 1.00$ ,  $\alpha_2 = 1.88$ ,  $\alpha_3 = 7.00$ . The process is implemented by using MATLAB7.0. It is verified by selecting the same time for three consecutive days in different starting and ending for authentication: Experiment A: A1-A2; Experiment B: B1-B2; Experiment C: C1-C2.

The basic ant colony algorithm and the improved ant colony algorithm were compared in timeliness and actual journey time.

#### 4.1. Algorithm Simulation Test

Tests are written by Using MATLAB. The timeliness of the algorithm is made a comparison firstly.

As can be seen from Figure 6, It can be seen that the improved ant colony algorithm on the convergence rate is better than basic ant colony algorithm in terms of timeliness or optimization capabilities.

As can be seen from Experiment A, the two curves are not substantially changed after 50 iterations. However, the improved ant colony algorithm has got its optimal value after 28 iterations. It can be seen that the improved ant colony algorithm on the convergence rate is significantly better than basic ant colony algorithm. As can be seen from Experiment B, optimal path weights obtained from improved ant colony algorithm is lower than that from basic ant colony algorithm, so the calculation speed of improved algorithm increase significantly. Experiment C proved once again the conclusions of A and B.

#### 4.2. Actual Travel Time Test

For different algorithms, we made actual travel time text. As same weight value is obtained from A, two different algorithms in B and C will be tested.

Experiment B ,ant colony algorithm path is: B1-v19-v14-v8-v7-v6-B2. It contains five intersections, v19-v14 and v8-v7 road are congested to delay travel time. Improved ant colony algorithm path is: B1-v19-v18-v15-v16-v6-B2. Five intersections are contained.

Experiment C, ant colony algorithm path is: C1-v2-v9-v8-v7-v6-v16-C2. Six intersections are contained. v8-v7 is congested to delay travel time. Improved ant colony algorithm path is: C1-v2- v3-v4-v5-v6-v16-C2, six intersections are contained, while the path is smooth.

The improved ant colony algorithm can reduce the user's path travel time according to Table 1. The results are shown in Table 1.

Table 1. Comparison of Actual Travel Time

Algorithm	Basic ant colony algorithm	Improved Ant Colony Algorithm
(B)	(B)41 min	(B)30min
(C)	(C)32 min	(C)25min

In summary, improved ant colony algorithm is superior to basic ant colony algorithm in timeliness and selection of optimal path, and users can quickly find the optimal path to drive.

#### 5. Conclusion

The optimal path algorithm of urban real-time traffic is based on ant colony algorithm for rectangular restrictions and limitations direction, determined weights by the real-time traffic and distance, and considering intersection. Through the actual test, conclusions are as follows:

(1) We can calculate the optimal path in a short time through rectangle restriction and direction restriction for the ant colony algorithm,

(2) The optimal path, whose weight value is determined by real-time traffic and distance and is added by the intersection turning factors, can help the users get to their destination within a short time and with less fuel.

(3) If there is emergency situation and the user wants to re-select the optimal path, the algorithm will re-select the optimal path based on regarding the location of user as a starting point.

In conclusion, the optimal path algorithm of real-time traffic has high validity and practicability for car users in the city.

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