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Urban Disaster Prevention and Emergency Material Distribution Based on Ant Colony Algorithm

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Abstract

Targeting at quantitative analysis of urban comprehensive disaster prevention planning, combining process architecture and method of multiple-target collaborative system on the basis of transforming bridge method, the paper puts forward a decision-making system of transforming bridge of urban disaster prevention planning on the basis of ant colony algorithm. First of all, we devise target function from three aspects respectively are time factors, security factors and economic factors. We create vehicle tracks of emergency logistics distribution in urban disaster, then making use of the effectiveness, randomness and global convergence in the early process in solving the algorithm. In the later process, we can make use of ant colony algorithm and immune algorithm to acquire optimized answers, generating initial information distribution. Then we take advantage of the positive feedback and parallelism of ACA to improve the solving effectiveness. The simulated experiment proves that the optimized algorithm, in comparison with standardized algorithm, can better prevent urban disaster and has better convergence.

Key words: Urban Disaster Planning; Emergency Logistics; Track Optimization; Immune Ant Colony Algorithm; Transforming Bridge

1. INTRODUCTION

Urban comprehensive disaster prevention plan means to conduct comprehensive deployment, specific arrangement and implementation management on relative urban land utilization, spatial arrangement and disaster prevention engineering (Zdamar, 2004). Its planning target is to give due consideration to integrated disaster and various disasters (Ozdamar, 2005). Hence, the stuff should deal with many multiple-target decision-making problems. And as the complexity of the urbanized function itself and inaccuracy of derivative changes of the disaster, the process of decision-making is very difficult. Usually we can only rely on the subjective experience of the stuffs.

To consult on experts has been the hot research of urbanized planning in making a decision. Extension strategy generation technique is based on extension theory. It uses formalized element expression to simulate the thinking model of human beings, and quantitatively gives solutions. In early decision-making system researches of intelligent urbanized planning, using extension strategy to make some strategies of urban master planning has been already put into practice (Yaevz, Arikan and Arikan, 2005). While transforming bridge is set on the idea of "take one's own roads, and one will be in his proper place", based on the method of coexistence by connecting or separating (Lee and Su, 2003). Its specific way of thinking can exactly be used into the making of multiple decisions of urban comprehensive disaster prevention (Cao, Liu, Wang Y, et al., 2013). This method makes use of problem model and correlation function to finish automatic collection and classification of the problems, transforming this problem into current target and condition. Then we make use of extension analysis and extension changing to produce diaphragm and interconnection method, forming initial strategy. Finally we make use of correlation function of the rule base to test whether the transforming bridge can become strategy and give the planning result. We make use of superiority evaluation to optimize multiple decisions (Coutinho-Rodrigues, Sim and Antunes, 2011). Different from early simple extension method, the generation type of the transforming bridge takes account of other subordinate targets when achieving the main targets (Curl, Nelson and Anable, 2011). On the basis of extension theory, the paper introduces the method of transforming bridge. After conducting extension analysis according to problem base and inference rule base, the paper transforms the comprehensive multiple-disaster prevention problem into conditional transition problem, respectively generate diaphragm and connected transforming bridge and gain initial method as the input information of generation process to evaluate and test (Davis, Gorsevski and Donevska et al., 2011). The paper combines the process architecture and method of multiple-target collaboration on the basis of transforming bridge way of thinking, putting forward a decision-making system of urban disaster prevention planning based on ant colony algorithm, carrying out instance simulation to prove the effectiveness of this method.

2. MODEL BUILDING OF EMERGENCY SUPPLY DISTRIBUTION IN URBAN DISASTER PREVENTION

2.1. Description of the Model

(1) Supposing there is a center of emergency supply distribution of urban disaster prevention and several crisis locations which need service. And the time of discharge should also be concerned.

(2) Supposing the quantities of supplies that each crisis location need to be known, and the supplies are limited. But at the same time, the quantity demanded in some time can be forecast. The reserved supplies in the center can satisfy the demand currently and in the future.

(3) Because the time of emergency logistics is limited, the relief materials that each crisis location needed can only be distributed in advance, otherwise the track is useless, which means vehicle scheduling should be reckoned by time.

(4) The transport line between the center and crisis location is incomplete network, which means each line is not unblocked, and can disconnect at times. The influence of road attribute to vehicles should be considered.

(5) Supposing that there are multiple vehicles distributing at multiple times, the distance between the vehicles and the center should be considered.

On the conditions above, we adjust the quantities of the vehicles expected to arrive on time to realize the optimization of track choosing.

2.2. Model Building

(1) Target function that considers time factors.

$$\min T = T_1 + T_2 \tag{1}$$

$$T_1 = \sum_{i=0}^{m}\sum_{j=0}^{m}\sum_{k=1}^{n} t_{ijk} q_{ijk} \tag{2}$$

$$T_2 = \sum_{i=0}^{m}\sum_{j=0}^{m}\sum_{k=1}^{n} \eta_{ijk} d_r q_{ijk} \tag{3}$$

Among which, the total time of distribution that all vehicles in equation (2) has used:

$$t_{ijk} = \frac{\eta_{ijk} \cdot D_{ijk}}{V_k \cdot \beta_{ij}} \tag{4}$$

t_{ijk} represents time used of the k vehicle from crisis location i to j ; V_k is averages speed of the k vehicle; β_{ij} is influence coefficient that the road condition of each crisis location has to the speed of the vehicles; q_{ijk} is decision variables.

In equation (3), T_2 is time of discharge of all vehicles; η_{ijk} is conversion coefficient between disaster response of the vehicles and the demand, $\eta_{ijk} = 0.7^{M_j}$. M_j is the normalized supply, $M_j = g_j / \sum_{j=1}^{m} g_i$. Set $\eta_{i0k} = 0$ to show that vehicles coming back to the center is not considered.

Besides, on the condition of time window, there are such constraint conditions:

$$t_i \le t_0 \tag{5}$$

Among which, t_0 is the last time; t_i represents time spent on the way to the crisis location such as t_{ijk} in equation (4). $\sum_{r=1}^{l} d_r$ represents the sum of time of discharge before the vehicle reaching crisis location i , r is a random crisis location before i , d_r is time of discharge at crisis location r before i .

$$t_i = t_{ijk} + \sum_{r=1}^{l} d_r \tag{6}$$

(2) Target function that considers security factors.

$$\min P' = \sum_{i=0}^{m}\sum_{j=0}^{m}\sum_{k=1}^{n} (-\lg P_{ijk}) \cdot q_{ijk} \cdot \lambda_{ij} \tag{7}$$

Among which, P_{ijk} is the probability of secure passing of vehicles in the track (i, j), there are q demand points in the road L, and the probability of the vehicles to pass safely is:

$$p_i(L) = p_{12} \cdot p_{23} \cdot \ldots \cdot p_{q(q+1)} \quad (8)$$

$$-\lg p_i(L) = -\lg p_{12} \cdot -\lg p_{23} \cdot \ldots \cdot -\lg p_{q(q+1)} \quad (9)$$

Set $-\lg P(L) = P'$, making P_{ij} be the highest, then we set the minimum value of $-\lg P(L) = P'$. λ_{ij} represents the effective coefficient between each road; q_{ijk} is decision-making variable.

(3) Target function that considers economic factors

$$\min C = C_0 + \sum_{i=0}^{m}\sum_{j=0}^{m}\sum_{k=1}^{n} D_{ijk} \cdot q_{ijk} \cdot R \cdot \alpha_{ij} \quad (10)$$

Set the opening cost of the reserve center as C_0; D_{ijk} represents the marched distance from crisis point i to j; R is the transforming formula of the cost and the marched distance of the vehicles; q_{ijk} is decision-making variable; α_{ij} represent influence coefficient the road condition has to the transportation expense of the vehicles.

Through weight value $w_p\,(p = 1, 2, 3)$ of each target, we transform multiple-target function to single-target function as:

$$\min Z = w_1 \times T + W_2 \times P + w_3 \times C \quad (11)$$

3. MODEL SOLUTION BASED ON IMMUNE ANT COLONY ALGORITHM

3.1. Realization of Immune Ant Colony Algorithm

(1) Input of antigen

First of all, we should design the operational process of immune algorithm, which means to input target function and constraint condition as antigen. The antibody of AIA applies natural number coding as its way of encode. Each antibody represents a character string, and each string represents a candidate solution of solution space.

(2)To generate and preconditioning the initial antibody

We encode according to natural number, use the randomly generated antibody as initial antibody and form antibody of the initial population, which is a candidate solution. Set N as the quantity of the group of antibody. We conduct preconditioning on each initial antibody, then we begin calculating and iteration so that the search efficiency of the whole algorithm can be improved. As for preliminary antibody $A = (c_1, c_2, ..., c_n)$, among which $c_1 = 1$, the specific operation that should be done to A.

(1) Calculate the fitness of the antibody

In bio-mechanism, once the antigen has generated, the corresponding antibody generate as well. Antibody concentration of the immune system is determined by antigen of the population. The higher the concentration is, the bigger proportion in the population this individual has.

(2) Using immune memory to generate new antibody and recalculate the fitness of antibody, in other words, the affinity and repulsive force between the antibody and the antigen. $affinityApp(B)$ and $affinityApp(B)$. If there is antibody correspondent with antigen in the new antibody, then we select new antibody and put it into taboo list so that the comparable optimized solution can be acquires. Otherwise we switch to step (5).

(3) According to natural selection mechanism of "survival of the fittest", among the new-born antibody, we select relative good antibody to correspond with antigen according to the concentration and auto-fitness of antibody. Otherwise we switch to step (2).

(4) Extract the immune algorithm in step (4) to acquire optimized solution, initiate parameters τ_C, τ_G, m, α, β, ρ, Q, and put m ants in n nodes.

Here, τ_C represent constant information, τ_G represent information. At the moment of beginning, we set initial value of information according to the equation above:

$$\tau_{ij}(0) = \begin{cases} \tau_C + \tau_G, if\ (i, j) = best \\ \tau_G, else \end{cases} \quad (12)$$

(5) Making m ants averagely distributed in each crisis location. If k ant is randomly at crisis location i , then the taboo list $tabu_k = i$, next the taboo list is updated constantly.

(6) As the information in the subordinate space accumulated incessantly, we calculate the choosing probability of each ant. In the process of information accumulation, we conduct updated operation on the leftover information set. According to condition we shift one ant to the next node.

(7) Calculate the security probability. Select the next shifting object according to the order of security probability. If accidents happen, select the tacks once again.

(8) Is the track of ant, if it violates the limited time of the constraint formula, then we back to step (8); otherwise we continue.

(9) Calculate the value of target function in the corresponding project and preserve the shortest track.

(10) Conduct local update of pheromone, after n moments, when the ants have climbed all the nodes, one single circulation has been finished. At this moment, we update pheromone of each track.

(11) Conduct iteration calculation and circulation algorithm until satisfying the algorithm.

(12) Judge from the end condition, output the optimized result.

3.2. Solution Method for Model

First of all, we set heuristic information. As for the emergency supply logistics of the n crisis locations, supposing that the codes of each crisis locations is $1, 2, ..., n$, and we set the center of emergency supply logistics as S , the others as $1, 2, ..., n$. Supposing that t_{ijk} is the time spent by the vehicles k from crisis location i to j ; P_{ijk} is the probability of secure passing from crisis location i to j of vehicle k ; D_{ijk} is the distance between center of emergency supply and crisis location. And heuristic information that the center has to the antigen is set as equation (13).

$$\eta_{ij}^k = w_1 / t_{ijk} + w_2 \times \lg P_{ijk} + w_3 / D_{ijk} \tag{13}$$

When considering the constraint condition, which is the deviation between relative optimized solution and the optimal solution, the calculation of the equation is shown as followed:

$$E^k = w_1 e_1^k + w_2 e_2^k + w_3 e_3^k \tag{14}$$

$$\begin{cases} e_1^k = (t^k - t^*) / t^* \\ e_2^k = [(-\lg P^k) - (-\lg P^*)] / (-\lg P^*) \\ e_3^k = (D^k - D^*) / D^* \end{cases} \tag{15}$$

Then we calculate the affinity and repulsive force:

(1) Calculation of affinity

In emergency logistic distribution path problem after the accident, to calculate affinity and repulsive force, we should define the formula of affinity first, which is expression of antibody A and antigen B such as equation (16).

$$Aff_{AB} = \frac{1}{T_A - T_B} \tag{16}$$

Among which, T_A represents antibody A , T_B represents antigen B . T_B , T_A are respectively the total length of the shortest track. We can replace T_B with proper positive number T_C ($T_C < T_B$), which can be defined as equation (17).

$$App_{AC} = \frac{1}{T_C - T_A} \tag{17}$$

When calculating Aff_{AC} , we need conduct division operation. Among which, T_C is relative bigger positive number, and at the same time, the total length of itinerary route correspondent with antibody should shorter than

T_C so that the positive value of Aff_{AC} can be ensured. Then we recreate and calculate the affinity between antibody and antigen. The affinity reflects the matching degree between antibody A and antigen C . The smaller the Aff_{AC} is, the worse matching degree is. Otherwise, the smaller the Aff_{AC} is, the better matching degree is.

(2) Calculation of the repulsive force

As for emergency supply logistics distribution problem, meanwhile we calculate $Rep(A_1, A_2)$, then we define the repulsive force between antibody A_1 and A_2 , which is shown as equation (18).

$$Rep(A_1, A_2) = | T_{A_1} - T_{A_2} | \tag{18}$$

Among which, T_{A_1} represents the total length of itinerary route correspondent with antibody A_1 . T_{A_2} represents the total length of itinerary route correspondent with antibody A_2 . The repulsive force reflects the difference between antibody A_1 and antibody A_2 . The bigger the difference is, the bigger is $Rep(A_1, A_2)$.

4.ANALYSIS OF THE ALGORITHM PERFORMANCE

To test the feasibility of this optimized algorithm, we conduct programming on the algorithm on the condition of MATLAB12.0, and we carry out a simulated calculation on the instance followed. Suppose that there is center of service facility S which is particularly used to preserve relief materials. At the same time, there are 10 crisis locations F1, F2, F3, F4, F5, F6, F7, F8, F9, F10. Now a batch of material should be distributed to each crisis location. The specific whereabouts of distribution center and distribution sites are located at a range of 100×100 kilometers.

4.1. Programming Simulation of Urban Disaster Prevention

Relative parameters are:

$\tau_C = 20$, $\tau_G = 2$, $m = 4$, $\rho = 0.6$, $\alpha = 2$, $\beta = 4$, $Q = 100$, $\omega_1 = 0.6$, $\omega_2 = 0.3$, $\omega_3 = 0.1$.

The total quantity of circulation of ant colony NC=10000. We respectively apply ant colony algorithm and immune ant colony algorithm to conduct experimental comparison on the problems above and gained the result which is shown as figure1, figure 2 and table1.

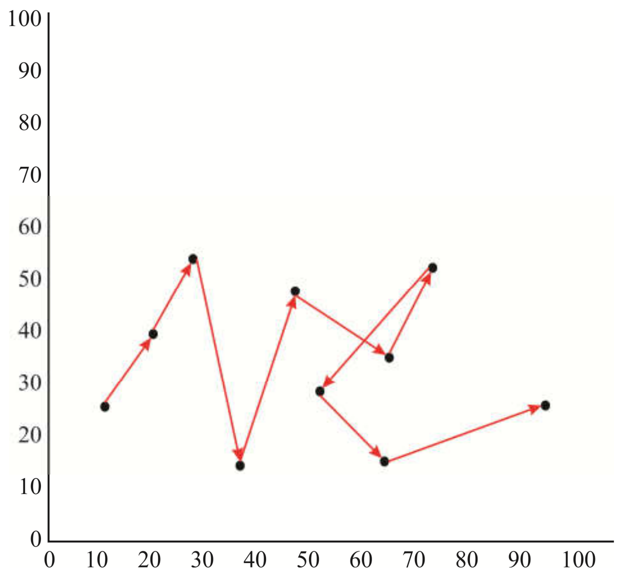

Figure 1. Once the optimal solution ant colony algorithm running route

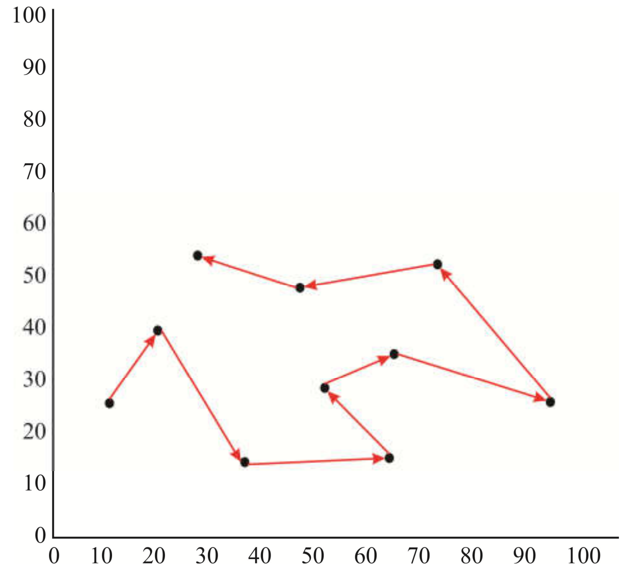

Figure 2. Immune ant colony once optimal running route

Table 1. Distribution route options and the corresponding results

	Ant Colony Algorithm	Immune Ant Colony Algorithm
Time consuming (H)	1.58	1.21
Transport distance (km)	139	110
The degree of risk ($-\lg$)	1.48	1.25
Cost (yuan)	1258.5	1001.2
General objective (ω)	112.4	101.7

From table1 we can see that, in the optimized project gained by immune ant colony, the first target is time-consuming, the second target is security, which means we should reduce the danger of distribution to the minimum degree. Secondly, we should consider cost. When the expense is acceptable, we target at the final aim. In comparison with ant colony algorithm, the immune ant colony algorithm owns better searching ability, and the gained result has been the best in time, balance and economy. Meanwhile, the immune ant colony algorithm has got over the deficiency of immune algorithm and genetic algorithm, of which the feedback information is inadequate and the solving efficiency is poor. This algorithm has stronger feasibility and can achieve the target of track optimization of urban disaster prevention in emergency supply logistics.

4.2. Simulation of Convergence

We use ant colony algorithm and immune ant colony algorithm to find solution, the result on condition of MATLAB is shown as picture3 and picture 4.

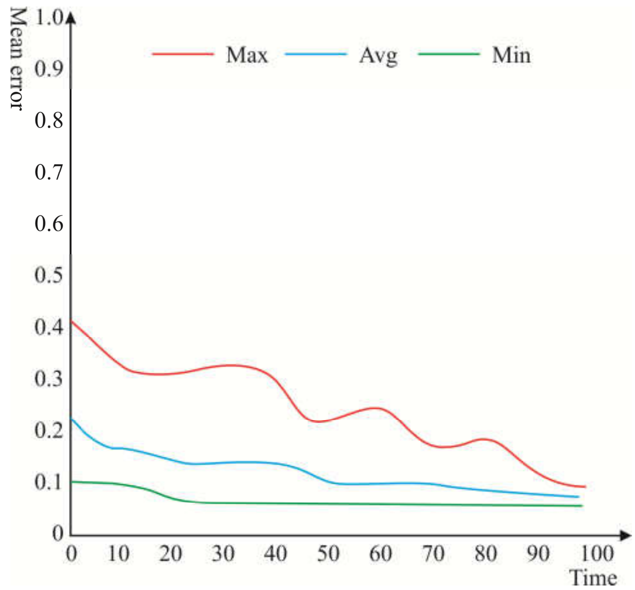

Figure 4. Convergence of the simulation results immune ant colony

From the location we can see that, through immune ant colony algorithm we can get better effect, the computational result has higher convergence and the rate of descent in the picture is faster. This is because the similarity of the antibodies has been considered. Then by calculating the concentration of antibody, we finally choose the antibody with smallest concentration. This leads to preservation of diversity of the antibody as well as the high fitness. It can also improve the local searching ability and fasten the searching speed and the general ability. Besides, it can avoid some individuals control the process of selection and at last there is the phenomenon of immature convergence. What's more, the immune memory ability it owns make the response quicker and efficient.

5. CONCLUSIONS

Urban disaster prevention planning is specialized planning of urban disaster prevention ability and space according to urban general programming. The essential attributes of urban planning is public policy, which is to make sure the security of the city and its people. And effective disaster prevention planning can reduce the danger of disaster, guaranteeing the security of urban and public interest. This paper combines the process architecture and method of multiple-target collaboration on the basis of transforming bridge way of thinking, putting forward a decision-making system of urban disaster prevention planning based on ant colony algorithm. The simulated experiment proves that in comparison with traditional ant colony algorithm, this optimized algorithm has better effect on urban disaster prevention and higher convergence.

REFERENCES

Cao J, Liu X C, Wang Y, et al. (2013) "Accessibility impacts of China's high-speed rail network", *Journal of Transport Geography*, 28, pp.12-21.

Coutinho-Rodrigues J, SimSo A, Antunes C H (2011) "A GIS-based multicriteria spatial decision support system for planning urban infrastructures", *Decision Support Systems*, 51(3), pp.720-726.

Curl A, Nelson J D, Anable J (2011) "Does Accessibility Planning address what matters? A review of current practice and practitioner perspectives", *Research in Transportation Business & Management*, 21(1), pp.3-11.

Davis L(2011) "What have we learned from 40 years 'experience of disaster shelter'", *Environ Hazards*, 10(3-4), pp.193-212.

Gorsevski P V, Donevska K R, Mitrovski C D, et al.(2012) "Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: A case study using ordered weighted average", *Waste Management*, 32(2), pp.287-296.

Liu Q, Ruan X, Shi P (2011) "Selection of eminency shelter sites for seismic disasters in mountainous regions: Lessons from the 2008 Wenchuan Ms 8.0 Earthquake, China", *Journal of Asian Earth Sciences*, 40(4), pp.926-934.

Lee Z J, Lee C Y, Su S F (2003)"An immunity-based ant colony optimization algorithm for economic load dispatch", *The Transactions on Evolutionary Computation*, 7(1), pp.83-94.

Yi W, Ozdamar L(2005) "Fuzzy modelling for coordinating logistics in emergencies", *Transportation Research Part*, 23(10), pp.123-125.

Yaevz E, Arikan F, Arikan O (2005). "A Hybrid Reconstruction algorithm for computerized ionosphere Tomography", *Recent Advances in Space Technologies*, 9(11), pp.782-787.

Zdamar L O (2004) "Emergency logistics planning in nature disasters", *Annals of Operation Research*, 12(9), pp.218-219.