The Forecast and the Optimization Control of the Complex Traffic Flow Based on the Hybrid Immune Intelligent Algorithm

Li Qing[1]*, Tao Yongqin[2], Han Yongguo[1] and Zhang Qingming[1]

[1]*School of Computer Science and Technology, Southwest University of Science and Technology, Sichuan, 621010, China;* [2]*College of Engineering, Xi'an International University, Shaanxi, 710077, China*

Abstract: Transportation system has time-varying, coupling and nonlinear dynamic characteristics. Traffic flow forecast is one of the key technologies of traffic guidance. It is very difficult to accurately forecast them effectively. This paper has analyzed the complexity and the evaluation index of urban transportation network and has proposed the forecasting model of the hybrid algorithm based on chaos immune knowledge. First of all, the chaos knowledge is introduced into the topology structure of immune network, so as to obtain the matching predictive values and knowledge base. Secondly, this algorithm can dynamically control and adjusted the regional search speed and can fuse the information obtained by the chaos and immune algorithm, in order to realize the short-term traffic flow forecast. Finally, the simulation experiment shows that the traffic flow forecasting error obtained by the method is small, feasible and effective and can better meet the needs of the traffic guidance system.

Keywords: Artificial immune algorithm, chaos search algorithm, knowledge discovery, traffic flow forecast.

1. INTRODUCTION

The urban transportation system is the carrier of all activities; it moves the materials that the entire urban system owes its existence and development to. Transportation experts are looking for ways to improve the performance of this system and to provide better services for more users. City subsystem itself is a complex giant system consisting of roads, subsystems (including subway and bus), traffic flow subsystem and management subsystem. There is the behavior that the travelers tend to make and change the travelling decision while in the system and this makes mechanism of the urban transport and operation very complex. Specific performance: 1) Traffic Engineering such as pedestrian-vehicleflow and roads, intersections, hub, etc. and control facilities are numerous, and all these components are closely related. 2) The pedestrian-vehicle flow is a highly intelligent system and is able to respond quickly to changes in the surrounding environment. It possesses self-organizing, adaptive and self-driven capabilities. 3) There are strong nonlinear interactions in the movement network of pedestrian-vehicle flow. 4) Urban transport system has a strong dynamic and randomness and is constantly changing and developing. 5) Openness of the system has further deepened the complexity of urban transport systems. With the expansion of urban areas resulting in increased distance and time for logistical, commercial and private vehicles, which adds to the uncertainty factors in the operation of the urban transportation system. Urban structure and function are more and more complex. The new situations and new problems appear constantly. Especially the mutual influences are more prominent between the traveler's choice, behavior and the changes of the network structure, transport facilities and management control measures. Therefore, the design of intelligent transportation system should encompass solution that includes an effective means of transportation safety and traffic congestion. Traffic guidance and traffic control is an important part of the intelligent transportation system. The accurate real-time traffic flow forecast is the premise and key of the intelligent traffic guidance and control. The traditional forecast methods, such as Kalman filter, MA, ARIMA are unable to fulfill the ever increasing requirements of the precision prediction. In recent years, some scholars introduced various types of artificial algorithm to predict traffic flow and have achieved some success [1-3]. But its shortcomings are the poor real-time, low prediction accuracy, slow speed optimization and difficulty to reasonably determine the network topology.

Modeling and optimal control in the complicated traffic flow systems often require high intelligence algorithms. But the existing single model evolutionary algorithms are often difficult to meet all performance requirements. The hybrid algorithm based on the chaos knowledge immune evolutionary (CKIEHA) uses the chaos algorithm strengths and knowledge immune intelligent algorithms internal policies to learn from each other, resulting in better optimization ability and solving efficiency. The immune system is a system of complex adaptive learning which has better pattern recognition capabilities and the stronger capability of the information processing. It shows good distribution, diversity, tolerance, new memories, adaptability and other characteristics. The immune system can combine congenital experience knowledge with acquired learning, combining to construct an adaptive dynamic system based on knowledge. It is easy for

*Address correspondence to this author at East 6A201, School of Computer Science and Technology, Southwest University of Science and Technology, Sichuan, China. Postcard: 621010; Tel:(+0086)18092066265;
E-mail: 364780516@qq.com

1874-1290/14 2014 Bentham Open

the system to absorb the advantages of elements of other intelligent systems to constantly improve its immune system evolution. But it has not been reported that the hybrid algorithm based on the chaos knowledge immune evolutionary is applied to the traffic forecast. The paper introduces the CKIEHA algorithm into real-time traffic flow forecast of the urban environment and combines with predictive ideas presented from similar period by the author which constructs the traffic forecasting model based on Chaos Knowledge Hybrid Immune Algorithm. To improve the timeliness of the prediction model, a network topology optimization algorithm based on chaos search theory is established. The experimental results show that the model is better than conventional methods in the forecast accuracy of the traffic flows and in the convergence terms of complexity network. It has the features such as the large space research ability, strong nonlinear mapping ability, better sound and dynamic target optimization capabilities, etc. It is suitable for forecasting complex nonlinear systems and has a good prospect to real-time traffic flow prediction.

2. COMPLICATED THE TRAFFIC PROJECTIONS

In recent years, with the further development of China's transportation system, peoples' requirements and expectation to the transport services are ever increasing. The urban transportation problems have become the bottleneck which restricts the healthy development of national economy [4]. To solve the contradiction problem between supply and demand imbalance in urban traffic, to research the strategy of sustainable development for urban transportation, efforts to achieve urban transport development goals with the resource sharing, orderly regulation, convenient and efficient, safe, reliable, environmentally friendly have become an important topic for urban development. In order to alleviate the tension of urban traffic, the operational management level of the existing transportation infrastructure must be improved. However, it cannot simply be relied on increasing the investment in transportation infrastructure to meet the growing traffic demands. Urban transport should focus on achieving transportation, balance between the supply and demand aspects, as so to reach software and hardware mutual complementation. As the urban transport system has a lot of randomness, complexity and uncertainty, people can only use intelligent methods (such as artificial immune algorithm, chaos algorithm, fuzzy control, neural networks, etc.) to carry through the related research. For this reason, many countries and cities are establishing more accurate and efficient traffic flows to forecast intelligent transportation systems [5].

However, due to the variability and complexity of the traffic flow, it is difficult to give precise analytical expressions to describe its variation rule. The dynamic prediction purpose makes the algorithm state change constantly to adjust and update the model, so that the predictive value are closer to the true value. Dynamic prediction of traffic flow parameters is one of the core content for traffic guidance and traffic control in intelligent transportation systems. Traffic incidents reflect that the traffic flow is not smooth and results in lower efficiency transportation system operation. According to the upstream and downstream sections of the traffic state, the dynamic prediction of traffic incidents can detect congestion and determine the traffic situation of the upcoming period quickly and accurately based on the dynamic prediction of traffic flow parameters to implement effective control.

The evaluation of the traffic forecast is particularly important in terms of predictive accuracy algorithms. In the evaluation of traffic flow forecasting a number of factors need to be considered in order to ensure the comprehensive advantages of its prediction accuracy, real-time forecasting, fuzzy portability and so on. This paper has adopted the fuzzy comprehensive evaluation method which is the core of engineering technology and constructed the two-level model of the fuzzy comprehensive evaluation, to carry out prediction accurately.

3. THE HYBRID INTELLIGENT ALGORITHM OF THE CHAOS KNOWLEDGE IMMUNE

Knowledge discovery technology has an extraordinary extraction process which can extract credible, innovative, effective and coherent user-friendly data from the mass of the traffic flow data. However, in the massive real traffic flow data which has a complex form of knowledge sources with uncertainty, incomplete quantity and quality. How to dig accurately out the potential, previous unknown and ultimately understand the knowledge of the intelligent transportation systems? It is the difficult problem of the knowledge discovery. The paper combines the chaos algorithm with the hybrid immune algorithm and applies them in the knowledge discovery. In the real database, according to the data sub class structure in the database category and equivalent relation of the attribute based on the construct category have been formed.

In the process of traffic flow knowledge focusing, the intelligent forecasting system requires to determine the focus. The heuristic coordinator finds the knowledge shortage of the traffic flow and forms the focus direction provided by the machine itself. But in practice, due to the combined problems of traffic knowledge nodes, it makes the search space very large and affects the search efficiency. However, the evolutionary mechanism of the hybrid chaos knowledge immunity can exert their strengths and help coordinate the quick search to form machine focusing. The big traffic flow data will continue to add new data along with the time increase and abandon the old data. The knowledge base of the traffic flow will continuously change along with the changes of the database content. Immune evolutionary mechanism can provide theoretical support and guidance to variation rule, reliability, robustness, optimization and evolution for the traffic flow knowledge.

1). The research of the dynamical behavior for the mode of the hybrid immune intelligent algorithm based on the chao knowledge

Dynamic mechanism is the sum of the motivation to promote a system for the development of the power to run and an integrated system consisting of a mechanism to maintain and improve a variety of economic relations and organizations [6]. For the evolution of internal system there must be proper dynamic mechanism. This mechanism corresponds to a kind of non-linear relationship; it is an asymmetric am-

Table 1. Evaluation index of traffic flow prediction.

No.	Name of Index	Calculation Method:(x_i is measured value of traffic flow parameters, $\hat{x}_i$ is forecast value, n is sample size)
1	average absolute error	$\frac{1}{n}\sum_{i=1}^{n}\left\|\hat{x}_i - x_i\right\|$
2	maximum absolute error	$\max\left\{\left\|\hat{x}_i - x_i\right\| \; \left\|i = 1,2,\cdots,n\right.\right\}$
3	average relative error	$\frac{1}{n}\sum_{i=1}^{n}\frac{\left\|\hat{x}_i - x_i\right\|}{x_i}\times 100\%$
4	maximum relative error	$\max\left\{\frac{\left\|\hat{x}_i - x_i\right\|}{x_i}\times 100\% \; \left\|i = 1,2,\cdots,n\right.\right\}$
5	mean square error	$\sqrt{\sum_{i=1}^{n}\left(\hat{x}_i - x_i\right)^2}$
6	equal Error	$1-\frac{\sqrt{\sum_{i=1}^{n}\left(\hat{x}_i - x_i\right)^2}}{\sqrt{\sum_{i=1}^{n}x_i^2}+\sqrt{\sum_{i=1}^{n}\hat{x}_i^2}}$
7	Linearity	$1-\frac{\sum_{i=1}^{n}\left(\hat{x}_i - x_i\right)^2}{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}$

plification mechanism with choice. It can choose, control, coordinate and guide the external or internal relationships according to the need of system evolution. The dynamic equation of traffic flow evolution process mainly refers to the evolution process of orderly mechanism and deeply describes the nature of the traffic systems by solving the mathematical model. This study uses chaotic variables to describe the many variables of the system state. Chaos is a general phenomenon in the nonlinear system. The chaotic motion has the characteristics of ergodicity, randomness, regularity etc. The chaotic motion can be exclusive ergodic in all state in a certain range by its own rule. The chaos can be applied to optimize the search and will undoubtedly have more advantages than the random search.

In order to ensure the traffic flow prediction without loss of generality, the paper takes a certain number of x_i to carry out the operation of the chaos and considers the following optimization problems:

$$\max f(x_1, x_2, \cdots, x_n)\,;\; a_i < x_i < b_i, i = 1,2,\cdots,n \tag{1}$$

In the formula, $[a_i, b_i]$ is x_i change interval; n is the number of variables optimized.

Determining chaos mapping and chaotic disturbance methods. For determining chaotic sequence:

$$\partial_{m+1} = \eta\partial_m(1-\partial_m) \tag{2}$$

In the formula, ∂ is chaotic variables, $0 < \partial_m < 1$; m is chaos iterations, $m = 1,2,\cdots$; η is control parameter. It is easily proved that when $\eta = 4$ the system is in a completely chaotic state. Its chaotic space is (0, 1).

For determining the random perturbation:

$$\beta_m^* = (1-\alpha)\beta^* + \alpha\beta_m \tag{3}$$

In the formula, β^* is the form of vector for after the current Optimal value $(x_1^*, x_2^*, \cdots, x_k^*)$ is mapped to the interval [0,1], is called optimal chaos vector. β_m is the chaotic Vector which is iterated m times; β_m^* is the chaotic vector which is applied to random disturbance In addition, $0 < \alpha < 1$, α can adaptively change. In the initial stage traffic flow search it is hoped that variables change is larger, α value is larger. With the traffic flow search variable gradually comes close to the optimal value, α should be gradually reduced. Algorithm determines the following formula:

$$\alpha = 1 - \left|\frac{m-1}{m}\right|^p \tag{4}$$

In the formula, p is an integer, according to the objective function determined. m is chaotic iteration time.

2). The design of the dynamic control and regulation based on the intelligent algorithm of knowledge immune in the search area

In the hybrid immune intelligent algorithm, the search area and size are two important factors that affect evolution

[7, 8]. With the growth of populations if the search area can continuously narrows, the optimal solution will be found if the speed is accelerated. But the size of the population can also reduce, that is, it will reduce the complexity of the algorithm. It is assumed that N_P evolution sub-populations search in a decision space $s=[a_1,b_1]\times[a_2,b_2]\times\cdots\times[a_{n_d},b_{n_d}]$, Now the r-th decision variables before narrowing is considered as the search area x. Its i-th decision-making the component is x_i. It ranges in the [a_i^{r-1}, b_i^{r-1}].

If,

$a^{r-1}=(a_1^{r-1},a_2^{r-1},\cdots,a_{N_d}^{r-1})$, $b^{r-1}=(b_1^{r-1},b_2^{r-1},\cdots,b_{N_d}^{r-1})$, Then $x^{r-1}\in[a^{r-1},b^{r-1}]$.

The condition of dynamic change in its search area is:

$$D^{r-1}<\lambda\bullet\left\|a^{r-1}-b^{r-1}\right\|_2,\ \lambda\in\left(0,\frac{1}{N_p}\right] \tag{5}$$

That is, if Equation (5) is satisfied. It changes the search area for next generation sub species, until the area is changes again. λ may be a fixed value, it can also be adaptively changed according to the evolution of the population.

Search granularity reflects the degree of the search refinement level. In general, the larger the population size is, the smaller the distance is between individuals. The smaller the particle size, the faster the search. Conversely the search size is relatively larger in [a_i^r, b_i^r] Search granularity is $\frac{1}{N_{ii}}$.

This coevolution sub-population scale is:

$$N_i^r=\left\lfloor\prod_{i=1}^{N_d}N_{ii}\bullet(b_i^r-a_i^r)\right\rfloor \tag{6}$$

where in $\lfloor\bullet\rfloor$ is the rounded down function, when the search area is reduced continuously, evolutionary population scale is proportionately reduced. This greatly reduces the computational complexity of the late evolution.

4. THE FORECAST AND OPTIMIZATION CONTROL OF THE COMPLEX TRAFFIC FLOW BASED ON CHAOS IMMUNE INTELLIGENT ALGORITHM BASED ON THE CHAOS IMMUNE INTELLIGENT

The forecast and control model of the complex traffic flow is as follow:

The system gathers the data of the traffic flows and it does not reach a certain amount it is temporarily stored in a

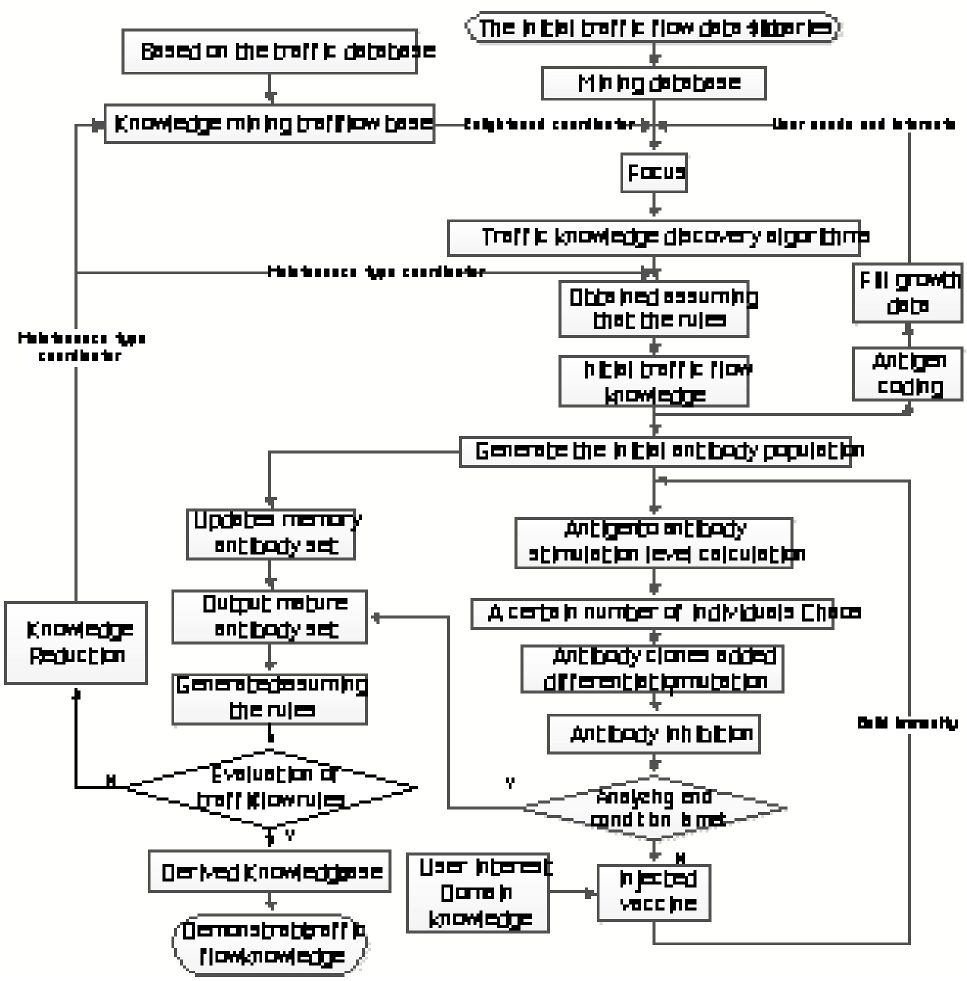

Fig. (1). The forecast and control flow figure of the traffic flow based on chaos immune intelligent algorithm.

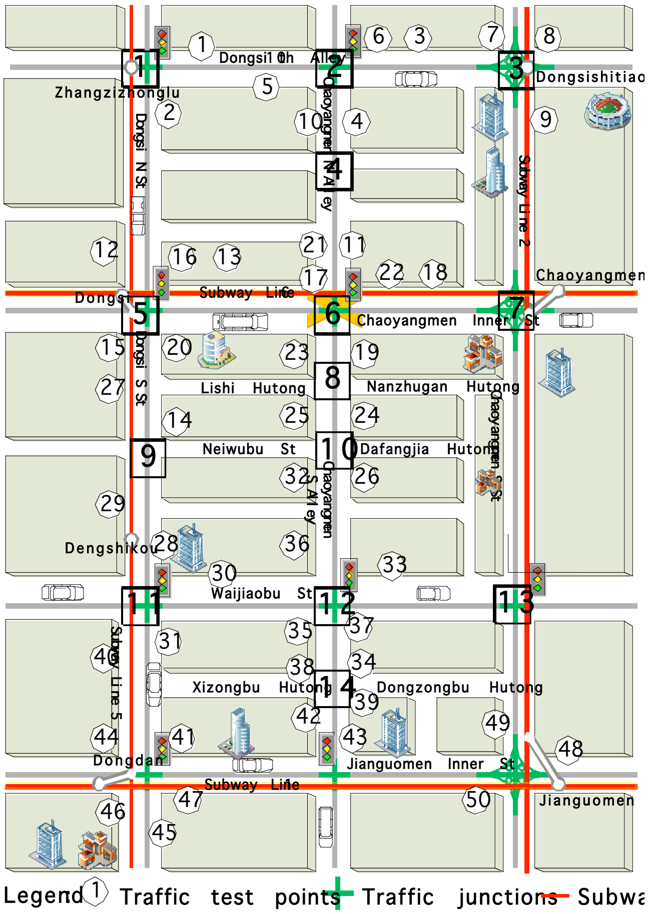

Fig. (2). the Bejing regional road network map.

buffer. After reaching a certain threshold the immune system will run and the initial populations are formed by the knowledge flow in the knowledge base of the traffic flow memory and the new traffic flow data gets identified. The calculated antibody is stimulated by the new antigen. According to its stimulation levels, the antibody will be cloned, value-added, differentiated, then he antibodies cloned carry out mutations, vaccine is injected and the new antigen is recognized, the calculated antibody is stimulated again. If there is need, it will enter mature stage. The moment maintenance coordinator transfers to restrain, recall and store the antibody. This has been the type of resistance from the traffic flow of knowledge with the dynamic changes of data. Every time after mining the knowledge evaluation of the traffic flow parameters of the comprehensive evaluation of the knowledge of history, thus forming dynamic change of the traffic flow knowledge. The specific step are as follows:

Step 1: Initializing the parameters of system and determining the range of each system parameter constraints;

Step 2: Introducing the knowledge discovery algorithms of traffic flow, calculating model and mining database According to parameters, getting the fitness function value of system error;

Step 3: Carrying out crossover and mutation operation and evolution for the hybrid immune algorithm of the chaos knowledge;

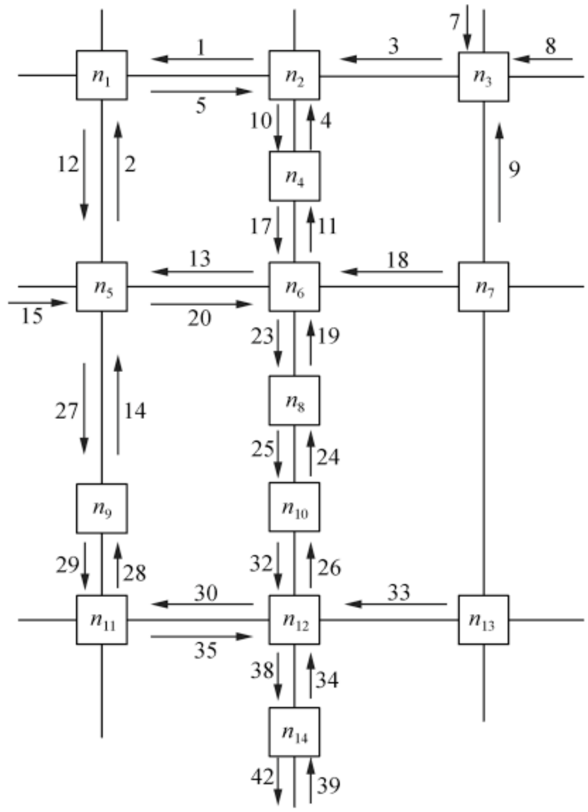

Fig. (3). The topology diagram of the regional road network.

Step 4. Judging algorithm termination conditions, and if the export antibody is mature, the traffic flow rules are generated, then turned to step 5. Otherwise, injecting vaccine and returning to Step 3;

Step 5. Judge rules of the traffic flow coming into the knowledge base of traffic flow and end operation if they are good, otherwise, the process the subsystem, return to step 2.

5. SIMULATION AND ANALYSIS

In order to verify the effectiveness and feasibility of the CKIEHA algorithm, this paper adopts the actual data of the traffic flow which are collected by the induction coil of Beijing second ring scoot control system. The subjects are the regional road network map which is surrounded by Beijing four roads, it is shown in Fig. (**2**).

The Fig. (**2**) shows the road network intersection of the regional, the flow direction and distribution situation of various sections of traffic flow. And then the network topological structure of the road network graph can be shown in Fig. (**3**). In order to simplify the graph, the Fig. (**2**) shows the regional road network and the traffic flow and distribution situation, the traffic flow of the left turn for 6, 16, 21, 22, 36, 37, 49, 50.and the traffic flow of no space-time dependent are not marked.

In order to analyze the forecast effect of model, using ARIMA, neural network and chaos immune three algorithms carry out forecast and the predicted results are compared. First, traffic flow data are integrated into 5 min, corresponds to 1 D having 288 data points. ARIMA model carry out fore-

Table 2. The evaluation index values of the traffic flow forecast.

Index Name of the Prediction Model	Average Absolute Error	Maximum Absolute Error	Average Relative Error	Maximum Relative Error	Mean Square Error	Equal Error	Linearity
ARIMA algorithm	7.01	24.0	7.15%	37.2%	9.30	0.927	0.940
Neural network algorithm	6.55	25.0	6.25%	34.0%	9.47	0.958	0.996
Chaos knowledge immune algorithm	5.19	22.0	6.0%	34.0%	9.5	0.980	0.976

Table 3. The membership grade for the evaluation index of the traffic flow forecast.

Index Name of Prediction Model		Average Absolute Error	Maximum Absolute Error	Average Relative Error	Maximum Relative Error	Mean Square Error	Equal Error	Linearity
ARIMA Algorithm	outstanding	0	0.3	0	0	0	0.27	0.4
	good	0.5	0.7	0.15	0.28	0.84	0.73	0.6
	general	0.5	0	0.85	0.72	0.16	0	0
Neural network algorithm	outstanding	0	0.4	0	0	0	0.96	0.99
	good	0.74	0.6	0.75	0.60	0.94	0.04	0.01
	general	0.26	0	0.25	0.40	0.06	0	0
Chaos knowledge immune algorithm	outstanding	0.81	0.05	0.32	0.57	0	0.98	0.95
	good	0.19	0.5	0.68	0.43	0.88	0.02	0.05
	general	0	0	0	0	0.12	0	0

Table 4. Comparative evaluation results.

Prediction method	ARIMA Algorithm	Neural network algorithm	Chaos knowledge immune algorithm
Judgment results	general	good	outstanding

cast for the number 39, 34, 35, 33, 26, 24, 19, 20, 18, 11, 4, a total of 11 sections. Selects the 120 data points of the 10 sections on the first day as historical data to predict the data of 168 data points on the day after and the results of the data points are averaged. The three models selected have mean absolute error, the maximum absolute error, average relative error, the maximum relative error, mean square error, the equal error, linearity as prediction error index. The prediction result in the three kinds of model is shown in Tables **2** and **3**.

From Tables **2** and **3** the results of the forecast and comparison can be drawn in Table **4**.

CONCLUSION

In the complex networks of modern intelligent transportation systems, according to the natural characteristics of the urban road network in the downstream sections of the regional road network and its upstream section of the traffic flow there clearly are the space-time dependent. Therefore, during the traffic flow forecast of the regional road network this feature of the urban road net workcan fully be used. By spatial and temporal characteristic analysis of historical traffic flow data, this paper adopts the knowledge of data mining to explore the hypothesis rule which is similar to the characteristics of traffic flow. The chaos optimization algorithm is applied to the topological structure of immune network and the matching values of the prediction are obtained with this algorithm to ensure accurate knowledge base. Then the two informations are mixed to achieve the prediction of short-term traffic flow. Through the experiments of Beijing city regional road network, results show that prediction errors are the smaller and can better meet the needs of traffic guidance system. They are feasible and effective.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

This work is supported by the Natural Science Research Project of Shaanxi Provincial Education Department in china (No.2013JK1122 and No.2013JK0428) and by the Education

Scientific Planning Project of Shaanxi Province (No.SGH13482). By the Education Reform Project of Xi'an International University(No: 2013B47). By the Planning Project of Shaanxi Provincial Science and Technology Department (NO:2014JM8352). By the Network Convergence Engineering Laboratory Open Fund of Mianyang City (No: 13zd3108).

REFERENCES

[1] C.-I Hou, "Traffic flow forecasting in leisure farm areas using artificial neural networks", *Przeglad Elektrotechniczny*, vol. 89, no. 1b , pp. 205-207 , 2013.

[2] M. Li, W. Hong, Kang Haigui, "Urban traffic flow forecasting using Gauss-SVR with cat mapping, cloud model and PSO hybrid algorithm", *Neurocomputing*, vol. 99, pp. 230-240 , 2013.

[3] K. Y. Chan , T. S. Dillon , E. Chang,"An intelligent particle swarm optimization for short-term traffic flow forecasting using on-road sensor systems", *J. Transport. Eng.*, vol. 60, no. 10, pp. 4714-4725, 2013.

[4] B. Yoon, H. Chang, "Potentialities of data-driven nonparametric regression in urban signalized traffic flow forecasting", *J. Transport. Eng.*, vol. 140, pp. 7-20, 2014.

[5] K.Y. Chan, T.S. Dillon, Chang E, "An intelligent particle swarm optimization for short-term traffic flow forecasting using on-road sensor systems", *IEEE Transact. Indust. Electron.*, vol. 60, no. 10, pp. 4714-4725, 2013.

[6] H. Qing, Z. Ran, L. Peng, "Dynamic reservation data scheduling mechanism for MPTCP", *Human Geogr.*, vol. 25 , no. 6 , pp. 820-3, 2013.

[7] R. Enayatifar, A.H. Abdullah, I.F. Isnin, "Chaos-based image encryption using a hybrid genetic algorithm and a DNA sequence", *Opt. Laser. Eng.*, vol. 56, pp. 83-93, 2014.

[8] L.F. Hsu, C.C. Hsu, T.D. Lin, "An intelligent artificial system: artificial immune based hybrid genetic algorithm for the vehicle routing problem", *Appl. Math. Informat. Sci.*, vol. 8, no. 3, pp. 1191-1200, 2014.

Received: June 09, 2014 Revised: September 22, 2014 Accepted: November 24, 2014