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Evaluation of incentive mechanism based on ant colony algorithm and neural network

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Abstract. In order to improve accuracy for incentive mechanism analysis of circular economy of minority areas in Sichuan, an analysis method for incentive mechanism combined with ant colony algorithm and neural network was proposed. Firstly, incentive mechanism selection of circular economy was converted to multi-target optimization, and feature dimension and classification accuracy were chosen to be assessment standard for feature selection. Ant colony algorithm was utilized to solve multi-target optimization, and optimal feature subset was found. Then neural network parameter was optimized by ant colony algorithm, and optimal incentive mechanism for circular economy of minority areas in Sichuan. Finally, specific incentive mechanism data for circular economy of minority areas in Sichuan was adopted to conduct simulation experiment. Simulation result shows that the optimal feature subset for incentive mechanism of circular economy of minority areas in Sichuan can be rapidly found through this method, and correctness rate and efficiency for incentive mechanism of circular economy of minority areas in Sichuan are improved.

Key words. Circular economy, Ant colony algorithm, Neural network, Incentive mechanism, Multi-objective optimization.

1. Introduction

Under the background of circular economy vigorously developed by the country, how to scientifically and reasonably evaluate development level for circular economy becomes key problem needs to be solved at present. In recent years, domestic and foreign literatures related to development evaluation for circular economy have emerged in large quantity. But researches on this development mode itself of circular economy are relatively few. Therefore, evaluation related to circular economy is mainly focused on construction for several sustainable development index systems,

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such as evaluation index system for "driving-state-response" proposed by Sustainable Development Commission of UN and human development index proposed by UNDP etc.

In recent years, domestic researches about circular economy have progressed rapidly, and research for circular economy has developed from idea diffusion and conceptual elaboration phase to construction stage for theory system. Connotation, development principle, operation mechanism and practical application etc. for circular economy were provided with relatively further research by many scholars. In terms of statistic evaluation for circular economy, with general recognition for development mode of circular economy and continuous deepening of circular economy practice, scholars generally think that scientific and reasonable statistic evaluation system for circular economy shall be established as soon as possible in research of circular economy, and construction thinking for evaluation system of all types was proposed. In view of circular economy evaluation involving many aspects of resource input, resource consumption and pollution discharging etc., research perspectives and emphases of different scholars are different, and circular economy evaluation system proposed has relatively larger difference. And it is more subjective. Most domestic scholars combine 3R principle with framework for "environment-economy-society-system". On the basis of reflecting "reduction, reuse and recycle", current development state for economy, society and ecological environment is considered. Circular economy shall be evaluated more respectively according to development for economic society and degree for environment improvement. Du Guangqiang (2006) constructed evaluation index system for circular economy development from four aspects of resource input, pollutants reduction, circular utilization and economic development. Wang Liying (2009), Guo Hui (2012), Wang Rong (2013) and Niu Xiaodong (2013) established index system covering development level, environment protection, resource reuse, resource consumption and waste emission of economic society.

Apart form overall level evaluation, there are index systems with an eye to circular economy innovation. Wang Maozhen and Feng Zhijun (2012) divided the whole index system into two parts of evaluation index for circular economy innovation and effect evaluation index for circular economy innovation. The former included green development concept index, technology support index, system and organization guarantee index. The latter was subject to 6 indexes for resource output index, resource consumption index, comprehensive utilization index for resource, waste discharging index, ecological environment index and development index for social economy etc.. 52 specific indexes were also included in the above 9 indexes, which formed three levels of index system. There were some scholars constructing index system according to analysis concept for energy value. Shi Baojuan (2006) started from perspective that circular economy essence was ecological economy to apply important method in ecological economic research-energy value to circular economy evaluation. Sustainable development index for circular economy system was taken as basic evaluation index, and net energy yield ratio (NEAR) for system, energy investment ratio (EIRE) and environment load ratio (ELR) were taken as analytical auxiliary indexes. System performance for circular economy was provided

with evaluation. Zhao Chen (2010) applied analysis method for energy value to construct energy value index system covering regional circular economy evaluation of 25 specific indexes from five aspects of energy value flow, energy value resource, society, economy and nature. Liu Hao et al. (2008) and Liu Zhijie (2011) applied analysis method for energy value to construct energy value index system for circular economy evaluation from five aspects of energy value flow, resource input and output, resource consumption, environment pressure and comprehensive index.

From comprehensive perspective of evaluation index system and evaluation research result for domestic circular economy, current researches mainly have the following shortages: firstly, evaluation index system is more simple combination for all kinds of resource environment indexes. Basic indexes that can actually reflect circular economy essence and development feature are not explored, and research is too subjective. All aspects for circular economy development can not be explained roundly; secondly, index for partial index evaluation system is too much, and mass repetitions exist in information; thirdly, in construction for theory index system, there is doubt for operability in evaluation, and data collections for many indexes are difficult. Practicability is limited; fourthly, adopted index is relatively numerous and jumbled and relation is complex. Use for evaluation method is lack of objective screening process.

Aimed at the above problems, the Thesis is subject to method for vector machine. Taking evaluation for circular economy development of provinces in China in 2012 as research objects, through establishing evaluation index system for initial circular economy of provinces in China, analysis method for main component was applied to extract main viable information, and score for main component was taken as input data. With the help of Libsvm 3. 18, evaluation model for circular economy based on support vector machine was established. Current state for circular economy development in China shall be described more objectively aimed at new perspective to scientifically evaluate and know development level for circular economy of province in China and to provide basis for formulating development strategy for circular economy.

2. Evaluation index for circular economy of minority areas in Sichuan

2.1. Index construction

Construction for one set of scientific, reasonable and feasible circular economy index system is the basis to conduct development level evaluation for circular economy. The Thesis is subject to fours aspects of economy, resource, environment and society to choose indexes that can reflect circular economy connotation, feature and principle. Index system has three levels, and they are target layer, criterion layer, measurement layer respectively from the top to bottom. Target layer is the highest layer that is overall condition and development level for circular economy construction of minority areas in Sichuan; system layer includes 4 subsystems, and they are respectively economic subsystem, resource subsystem, environment subsystem and

society subsystem. Final specific indexes shall be set for all subsystems according to different targets (as shown in Table 1).

Table 1. Structure framework for evaluation index system of circular economy

Target layer	Criterion layer	Measurement layer	Unit
	Economic subsystem	GDP per capita	Yuan
		Growth rate for GDP	%
		Proportion of the third industry to GDP	%
		Disposable income for urban residents	Yuan
		Rural annual pure income per capita	Yuan
		Proportion of fixed investments for the whole society to GDP	%
		Proportion of fiscal revenue to GDP	%
	Resource subsystem	GDP energy consumption per ten thousand yuan	Tons of standard coal/ten thousand yuan
		GDP water consumption per ten thousand yuan	Cubic meter/ten thousand yuan
		GDP electric consumption per ten thousand yuan	KWH/ten thousand yuan
		Disposal utilization for industrial solid waste	%
		Standard-reaching rate for industry sewage discharging	%
		Removal rate for industry dust	%
	Environment subsystem	Proportion of comprehensive utilization output value for "three wastes" to GDP	%
		Proportion of treatment investment for environment pollution to GDP	%
		Central treatment rate for urban domestic sewage	%
		Harmless treatment rate for urban domestic rubbish	%
		Quality index for biological environment	–
	Society subsystem	Proportion of output value for high-tech industry to GDP	%
		Proportion of urban population to the total population	%
		Proportion of student enrollment for high universities to the total population	%
		Proportion of general education expenditure to GDP	%
		Proportion of number of people participating in basic endowment insurance to the total population	%
		Park green area per capita	Hectare/ ten thousand people

2.2. Data obtaining

According to evaluation index system for circular economy in minority areas in Sichuan constructed in the previous part, data from 2000-2009 years was obtained. Data information was mainly from *China Statistical Yearbook* (2001-2010), *Hubei Statistical Yearbook* 02001∼2010), *Statistic Bulletin for National Economy and Social Development in (2000-2009) Years of Minority Areas in Sichuan* and *Environment Statistic Bulletin in (2000-2009) Years of Minority Areas in Sichuan*, and individual data was from websites for departments for Statistical Bureau of Minority Area in Sichuan and Environment Protection Bureau of Minority Area in Sichuan. Data of some years was missing. Considering importance of related indexes to evaluation, it was subject to moving average method to conduct interpolation.

3. Ant colony neural network

For training text library of text with large scale, dimension for its feature vector often reaches hundreds and even higher. For classifier, too many feature dimensions will cause problem of "dimension disaster". Equal training time and slow convergence rate easily cause defects of fitting and local optimum etc. of RBF neural network and finally affects analysis performance of incentive mechanism. Therefore, incentive mechanism vector for circular economy shall be provided with selection, and feature subset which is most important to classification shall be selected. Feature dimension shall be lowered, and redundancy shall be eliminated.

Ant colony optimization (ACO) has characteristics of positive feedback, global strong searching capacity and distribution calculation etc., and it is widely used in fields of job scheduling, network route and multi-parameter optimization of workshop. Relatively good effects are reached [12]. Therefore, incentive mechanism for circular economy shall be provided with selection by adopting anti colony algorithm.

3.1. Construction for assessment function

For incentive mechanism selection of circular economy, incentive mechanism for circular economy is deemed as one node visited by ant, and resolving for theses feature selection is deemed as process that ant seeks for the optimal path during foraging. Nodes (feature) that ants pass through during foraging are connected into foraging path (feature subset), and pheromone in every feature node shall be provided with corporation by groups through residual. Finally, better foraging path shall be found (better feature subset). Therefore, feature optimization shall be transferred to path search, and path construction and path formation for incentive mechanism selection of circular economy of ant colony algorithm is shown in Fig.1.

Selection targets for incentive mechanism of circular economy include two aspects: ①incentive mechanism for circular economy of minority areas in Sichuan shall be made more correct by selecting feature subset; ②feature dimension shall be made the minimum as much as possible. However, both are contradictory to each other. In order to balance both, function for advantage and disadvantage assessment of

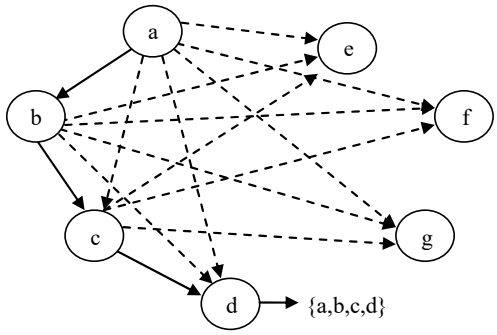

Fig. 1. Path formation process for incentive mechanism selection of circular economy

feature selection is defined as follows:

$$\max F = A + \lambda \frac{n}{N}\,, \tag{1}$$

Where, n is dimension of selection feature subset s; N is the total dimension for the feature set of text candidate; A is subject to recognition rate for the feature; λ is the maximum recognition rate of balance and weight of feature dimension; F is evaluation function value.

3.2. Transition probability

Transition probability of ants from feature i to feature j is:

$$p_{ij}^{k}(t) = \begin{cases} \dfrac{\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)}{\sum \tau_{is}^{\alpha}(t)\eta_{is}^{\beta}(t)} & j, s \notin tabu_k \\ 0 & otherwise \end{cases} \tag{2}$$

Where, η_{ij} is heuristic factor. The more the η_{ij} is, and the larger the probability of ants transferred to feature j; $\tau_{ij}(t)$ is pheromone of time t from feature i to feature j; $tabu_k$ is the taboo list for ant k.

3.3. Local search mechanism

It is supposed that after ant searches the i important feature f_m (feature set at present shall be marked S_m) at the time of t, the $i+1$ important feature f_n shall be searched through k secondary important feature. Therefore, local search shall be conducted in feature set $U(U \neq \emptyset)$ composed of k features. Any subset u_i of U shall be set, and it shall be marked $S_i = S_m \cup u_i \cup \{f_n\}$. The optimum subset shall be searched to meet:

$$F(S_j) = \min_i (S_i, \forall i)\ . \tag{3}$$

Feature set at present shall be modified to be S_j to make ant forget partial

secondary important features. These forgotten features are not related to feature or redundancy feature.

3.4. Updating rule for pheromone

When all ant colonies complete one structure of solution, recognition result for corresponding classifier of per solution can be calculated. Therefore, adaptive value for per ant can be got, and overall updating for pheromone shall be conducted according to Equation (4).

$$\begin{cases} \tau_{ij}(n+1) = \rho \cdot \tau_{ij}(n+1) + \sum_{k} \Delta\tau_{ij}^{k}, \\ \Delta\tau_{ij}^{k} = \dfrac{Q}{F(s_k)}. \end{cases} \tag{4}$$

Where, $F(s_k)$ is adaptation degree value for feature subset s; ρ is residual factor of pheromone; n is round iteration number; k is ant No.; Q is increasing concentration of pheromone.

In case there are no changes in the optimum adaptation degree function for several times of continuous iteration of ant colony, it means that search for ant colony algorithm is completed.

3.5. Selection process for incentive mechanism of circular economy

(1) It shall be provided with pretreatment through colleting text data.

(2) Extract incentive mechanism vector of circular economy.

(3) Set parameter for ant colony, including parameters of ant quantity M, the maximum iteration times $T_{\max}$ and α, β and ρ

(4) Produce initialization ant position at random.

(5) Iteration times T=1.

(6) Transition probability for per ant shall be calculated according to Equation (3). Then for the next node, a feasible solution shall be constructed. After ant colony completes one search, the optimum solution and pheromone at present shall be updated.

(7) Position for ant colony algorithm shall be provided with decoding to get corresponding feature subset.

(8) Feature subset shall be imported into RBF neural network for studying to get incentive mechanism result for circular economy in minority areas in Sichuan. Target function value shall be calculated through classification result and feature subset dimension.

(9) Iteration times increases T=T+1.

(10) It meets iteration finishing, and the optimum solution for ant colony algorithm shall be provided with decoding to get inventive mechanism subset of the optimum circular economy. Otherwise, it shall be transited to Procedure (5) to continuously conduct incentive mechanism selection of circular economy until the

optimum feature subset is found.

4. Computing process of algorithm

RBF neural network is one kind of feed-forward neural network of 3 layers, including input layer, hidden layer and output layer. RBF neural network is local approximation network. For every input and output data, a small quantity of weight shall be adjusted, and it has advantages of rapid learning, global approximation property and the best approximation performance. One RBF neural network is made up of n input nodes, m hidden nodes and 1 output node. Hidden node is RBF function, and it is expresses as:

$$h = \exp\left[-\frac{\|x-c\|}{2\sigma_2}\right], \tag{5}$$

Where, σ is width for RBF hidden node, and c is the center of the i RBF hidden node. W is output weight.

Parameters w,c and σ plays a decisive role in prediction of RBF neural network. For obtaining RBF neural network with high prediction, reasonable w,c and σ shall be obtained firstly. Parameter optimization method for traditional RBF neural network has its own deficiency. Therefore, the research was subject to anti colony algorithm to optimize parameters w,c and σ of RBF neural network.

5. Experiment analysis

5.1. Experiment construction

Evaluation model for circular economy development level in minority areas in Sichuan based on neural network is constructed next, and it is less than evaluation of constructed model applied to circular economy development level of 31 provinces, cities and districts in China. Construction process and solution result of model is shown as follows:

(1) Structure for neural network model of development level evaluation of circular economy. BP network shall be applied to evaluation for development level of circular economy in minority areas in Sichuan, and BP neural network is made up of input layer, hidden layer and output layer of several nodes. Node quantity in input layer is equal to quantity for evaluation index. Output layer is one node, and it represents level for development level for regional circular economy. Element number in hidden layer shall be determined according to input unit and output unit.

(2) Confirm grading standard for development level of circular economy. Grading standard of index in the research shall be on the basis of the following principles: ① existing indexes for national standards and international standards shall be subject to specified standard values as much as possible; ② current situation values for developed countries and developed areas shall be taken as reference values; ③ current situation value in minority areas in Sichuan shall be taken as reference value.

According the above principles, 24 indexes for per capita GDP, energy consump-

tion for per GDP, water consumption per GDP and quality index for ecological environment in Table 1 shall be divided into 5 levels, and specific grading for partial index is shown in Table 2. At the same time, training expectation values for neural network corresponding to all levels are given. Confirmation for grading standard for development level of circular economy can not only be used in horizontal comparison between different areas, and can also be used in vertical comparison of different development stages in the same area.

Table 2. Partial index grading for development level of circular economy

Index	I level	II level	III level	IV level	V level
GDP per capita (*10^4yuan)	>= 2	1.6∼2	1.2∼1.6	1∼1.2	<= 1
Proportion of the industry to GDP (%)	>= 70	50∼70	40∼50	30∼40	<= 30
GDP energy consumption per ten thousand yuan (tons of standard coal /ten thousand yuan)	<= 1	1∼1.2	1.2∼1.3	1.3∼1.4	>= 1.4
GDP water consumption per ten thousand yuan (cubic meter/ten thousand yuan)	<= 200	200∼300	300∼400	400∼500	>= 500
Standard-reaching rate for industrial sewage discharging (%)	>= 98	95∼98	90∼95	80∼90	<= 80
Removal rate for industrial dust (%)	>= 98	95∼100	90∼95	85∼90	<= 85
Central treatment rate for urban domestic sewage (%)	>= 90	70∼90	50∼70	30∼50	<= 30
Quality index of ecological environment	>= 75	55∼75	35∼55	20∼35	<= 20
Proportion for hi-tech industry to GDP	>= 50	40∼50	30∼40	20∼30	<= 20
ANN expected value	5	4	3	2	1

5.2. Evaluation result

According to evaluation standard for circular economy, indexes in all subsystems all have the upper limit or the lower limit. When all index values are within the specific scope of some kind of index, overall level for circular economy falls into corresponding category at this time. Therefore, in case random value selection (or average value selection) is conducted within corresponding index scope, and enough training scope for development level of all kinds of circular economy can be generated. 1000 samples are generated randomly in the Thesis, and Shao Shi extracts 150 samples respectively randomly to be as detection samples and test samples. The rest 700 samples shall be taken as training samples. Theory output values for training sample shall be taken as 5, 4, 3, 2 and 1 (corresponding to I –V level development level of circular economy). For index data has certain dimension, index data shall be provided with standardized treatment. Finally, index import shall be imported with trained neural network model to conduct evaluation after standardized treatment of index. Firstly, development level for four subsystems of circular system shall be

respectively evaluation, and comprehensive development index for circular economy in minority area in Sichuan shall be comprehensively evaluated.

The Thesis is subject to tool box of version 7.0 for artificial neural network of Matlab to call related orders and training and computing process that do not need complex programming for finishing network. For network of overall development level in minority areas in Sichuan, when iteration times are 90, network error is far less than 0.0001. Curve Diagram for Mean Square Error of BP Neural Network (MSE), Error Distribution Diagram of BP Neural Network and Regression Analysis Diagram for Practical Output and Expected Output are shown in Fig.2-4. It can be seen form these diagrams that network has stronger generalization capability, and network can applied to comprehensively evaluate development level for circular economy in minority areas in Sichuan. For four subsystem network, the same conclusion can be obtained.

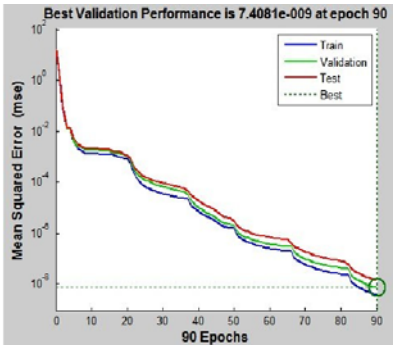

Fig. 2. Curve for mean square error of bp neural network

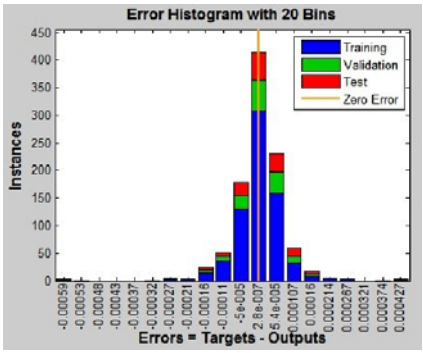

Fig. 3. Regression analysis diagram for practical output and expected output

6. Conclusion

On kind of analysis method for incentive mechanism combined with ant colony algorithm and neural network was proposed in the Thesis, and incentive mechanism selection of circular economy was transferred to multi-target optimization. Multi-target optimization was solved by taking advantage of ant colony algorithm, and the optimum incentive mechanism for circular economy in minority areas in Sichuan was established. Simulation result shows that the optimal feature subset for incentive mechanism of circular economy of minority areas in Sichuan can be rapidly found through this method, and correctness rate and efficiency for incentive mechanism of circular economy of minority areas in Sichuan are improved.

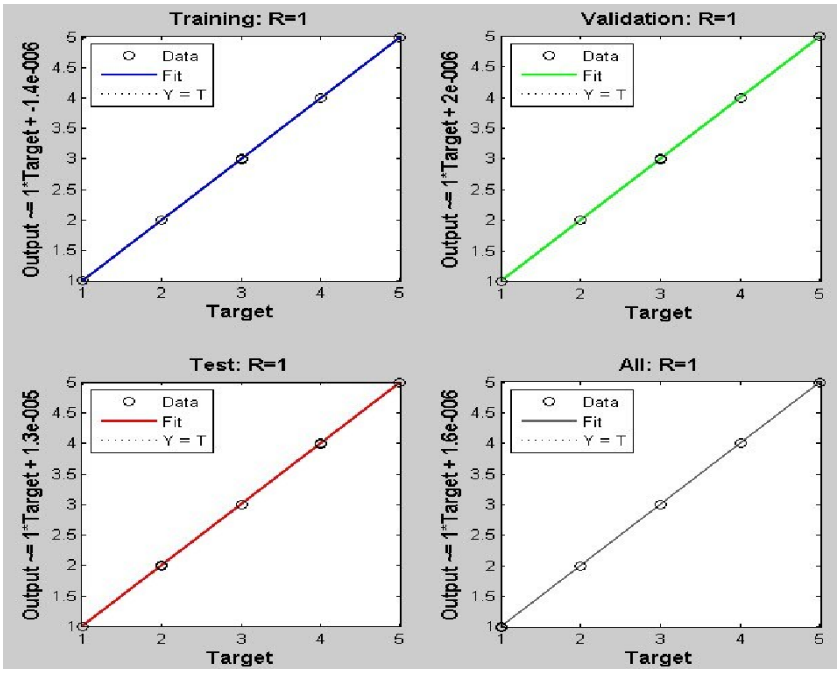

Fig. 4. Regression analysis diagram for practical output and expected output

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