Evaluation of regional economic development level based on grey clustering and rough set

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Abstract

The evaluation result of regional economic development is an important basis for government to make regional economic development planning, scientific regional economic development evaluation system and method has an important significance for understanding the regional economic development. Using grey clustering to classify different regions by the new evaluation index system, and using the rough set theory to derive fuzzy decision rules, these rules can explain the preference behaviour of decision makers and provide scientific and rational decision-making suggestions.

Keywords: Regional economic, Grey fixed weight clustering, Dominance rough set, Evaluation, Decision rules

1 Introduction

Regional economy is the foundation of the national economy. It can reflect the development level of economy accurately and systematically as well as objectively measure the economic development process; it has strategic significance to provide accurate and scientific statistical data for the leaders in time. Therefore, it has important practical significance to establish an accurate and systematical index system, which can measure and evaluate the level of regional economic development.

Many scholars have already made an investigation on the evaluation of regional economic development. Song Malin has adopted factor analysis and regression analysis to evaluate the economic development of Anhui province comprehensively [1]; Luan Jinchang etc. has adopted the entropy theory to determine the index weight, then used AHP to evaluate the cities level economic [2]; Wang Xiaoliang has constructed the evaluation index system including 24 indicators of regional open economy development level from 4 aspects: opening up foundation, scale, architecture, and efficiency, taking the seven provinces and municipalities in the eastern coastal with higher degree of opening as an example, adopting the improved entropy method to evaluate and sort the level of the seven provinces of the open economy in 2010 [3]; Sheng Minglan has constructed the evaluation index system and evaluation model for the county (district) level of economic development. Based on AHP and grey correlation method, She has got the multi-level grey evaluation model and made use of three aspects of economic strength, prosperity, development speed so as to evaluate the domain of the economic development level of the 40 counties (District) in Chongqing city[4]; Wang Xizhao etc., based on the five aspects of scale as economic stock index, benefit index, structure index, pressure index and prosperity index, has adopted factor analysis method to evaluate the level of economic development of Qianxi County, and clustered using SAS program [5].

Above all, there are many researches on the existing literature concern regional economic development level, but many evaluation methods are quite subjective and relatively simple, which subjectively determine the weights of the evaluation without simplify indicators. Therefore, an objective evaluation of the regional economic development and the deriving of decision rules will create great practical significance. This paper has adopted entropy method to determine the weight of indicators, adopted the method of grey fixed weight clustering to classify the regional economic development level of 17 cities of Shandong, and derived the decision rules by using the method of rough set. It can provide the important reference basis to the regional economic development for the local government to make the planning and decision.

2 Grey clustering and rough set theory

In the face of uncertainty decision problems, if policymakers want to make quick decisions, they have to prepare effective analysis and processing tools while rough set theory is a powerful tool for data processing. Rough set theory can deal with imprecise, uncertain and

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incomplete data. It can effectively analyse incomplete information, which has been successfully applied to knowledge acquisition, decision analysis, prediction, expert system and knowledge discovery in database and many other fields. However, with some of disadvantages, the rough set theory cannot solve every problem. Only when it has combined some other theories such as grey system, neural network, probability statistics, fuzzy sets of two or more complementary heterozygous and build more powerful hybrid soft decision method, expand the rough set theory of applicable scope, can it deal with uncertainty decision problems effectively. However, the decision table of rough set must be given in advance, and we can only establish information system based on dataset without acquire the decision table. Besides, clear approximation space will always be met, and the decision attribute values are always fuzzy. As a result, we could not obtain probabilistic decision rules [6-8]. This paper has adopted a hybrid method of rough sets and grey clustering. Generate the decision table of rough fuzzy sets by using grey clustering method, then reduction and approximate method for the attribute so as to acquire decision rules.

2.1 GREY FIXED WEIGHT CLUSTERING

Grey clustering is method based on grey correlation matrix or grey whitenization weight function so as to divide some observation index or observed object into defined categories.

Let $x_{ij}(i=1,2,\cdots,n;\ j=1,2,\cdots,m)$ as the observation object i index of the j value, $f_j^k(\cdot)(j=1,2,\cdots m;k=1,2,\cdots,s)$ as k whitenization weight function of j index. If the weight $\eta_j^k(j=1,2,\cdots,m;k=1,2,\cdots,s)$ of subclass k are independent with k, for arbitrary $k_1,k_2\in\{1,2,\cdots,s\}$, always has $\eta_j^{k_1}=\eta_j^{k_2}$, the k of η_j^k can be omitted, denoted as $\eta_j(j=1,2,\cdots,m)$, and $\sigma_i^k=\sum_{j=1}^{m} f_j^k\left(x_{ij}\right)\eta_j$ is called the grey fixed weight clustering coefficient that the object i belongs to the grey type k; if for any $j=1,2,\cdots,m$, always has $\eta_j=\frac{1}{m}$, then called $\sigma_i^k=\frac{1}{m}\sum_{j=1}^{m} f_j^k\left(x_{ij}\right)$ grey equal weight clustering coefficient for object i belongs to the k grey class.

Clustering objects are classified according to the grey fixed weight clustering coefficient called grey fixed weight clustering.

The steps of Grey fixed weight clustering:

(1) Gives the subclass of k of j indicators' whitenization weight function $f_j^k(\cdot)(j=1,2,\cdots m;k=1,2,\cdots,s)$.

(2) Determine the index clustering weight $\eta_j(j=1,2,\cdots,m)$.

(3) From the 1, 2 step of the whitenization weight function of $f_j^k(\cdot)(j=1,2,\cdots m;k=1,2,\cdots,s)$, the clustering weight $\eta_j(j=1,2,\cdots,m)$ and observations $x_{ij}(i=1,2,\cdots,n;\ j=1,2,\cdots,m)$ of the object i index of j, calculated the grey fixed weight clustering coefficient $\sigma_i^k=\sum_{j=1}^{m} f_j^k\left(x_{ij}\right)\eta_j\ (j=1,2,\cdots m;k=1,2,\cdots,s)$.

(4) Get the clustering coefficient vector $\sigma_i=\left(\sigma_i^1,\sigma_i^2,\cdots,\sigma_i^s\right)$ by grey fixed weight clustering coefficient.

(5) Clustering coefficient matrix

$$\Sigma=\left(\sigma_i^k\right)_{n\times s}=\begin{bmatrix}\sigma_1^1 & \sigma_1^2 & \cdots & \sigma_1^s\\ \sigma_2^1 & \sigma_2^2 & \cdots & \sigma_2^s\\ \vdots & \vdots & \ddots & \vdots\\ \sigma_n^1 & \sigma_n^2 & \cdots & \sigma_n^s\end{bmatrix}. \quad (1)$$

(6) If $\max_{1\le k\le s}\left\{\sigma_i^k\right\}=\sigma_i^{k^*}$, then determine the object i belongs to the grey k^*.

2.2 DOMINANCE ROUGH SET THEORY

In many problems, learning classification is a class of problems that has been widely studied. Rough set theory is a powerful tool for reasoning about data. And learning system, based on rough set theory, is the essence of that classification problem given attributes redundancy and dependence. Rough set theory is based on such assumption; each object and some information in the domain of discourse were linked while the same amount of information describing the object cannot be distinguished. The indiscernible relation generated by this manner is a mathematical basis of rough set theory. However, in many actual problems, the consideration of sequence characteristics of preference is important [9-10]. With a dominance relation instead of indiscernible relation, an important consequence of this treatment is that it can derived preference model by case decision.

2.2.1 Dominance relation

Let $x,y\in U$, $P\subseteq C$, if for $\forall q\in P, f(y,q)\ge f(x,q)$, then the relationship of yD_Px is called the dominance relation. This definition of dominance relation actual is weak dominance or partial order relation, expression of the object set in preference a preference on q. Give $P\subseteq C$ and $x\in U$, $y\in U$. On the $P-$ dominating set and $P-$ dominated set of x respectively:

$$D_P^+(x)=\{yD_Px\}, \quad (2)$$

$$D_P^-(x)=\{xD_Py\}. \quad (3)$$

Assuming decision-makers recommend that, the object set U is divided into a finite number of decision classes, let $Cl=\{Cl, t\in\{1,2,\ldots,n\}\}$, then $Cl_n \succ \ldots \succ Cl_t \succ \ldots \succ Cl_1$, class to set union and downward respectively:

$$Cl_t^{\geq}=\bigcup_{s\geq t} Cl_s, Cl_t^{\leq}=\bigcup_{s\leq t} Cl_s, t,s\in\{1,2,\ldots,n\}. \quad (4)$$

The statement $x\in Cl_t^{\geq}$ means " x at least belongs to the category of Cl_t "; the statement $x\in Cl_t^{\leq}$ means " x most belongs to the category of Cl_t ". From here we can see, the each object of the up union $Cl_t^{\geq}$ is better than or at least equal to each object of the down union $Cl_t^{\leq}$. Obviously, $Cl_1^{\geq}=Cl_n^{\leq}=U, Cl_n^{\geq}=Cl_n$. In addition, for $t=2,\ldots,n$, then $Cl_{t-1}^{\leq}=U-Cl_t^{\geq}, Cl_t^{\geq}=U-Cl_{t-1}^{\leq}$. In other words, policymakers have made decision table object assigned to Cl categories according to the following of the comprehensive evaluation: the difference in the Cl_1 class, the best in class Cl_n, and other objects belonging to the rest of the class Cl_t. According to this principle, if $t\in\{1,2,\ldots,n\}$ is larger, then the category Cl_t is better.

2.2.2 Dominate rough set approximation

Assuming the knowledge represents system $S=(U,A,V,f)$ as partial multi-attribute decision table, $A=C\bigcup D$, given the preference information's attribute set $P\subseteq C, x\in U, Cl_t\subseteq D, t\in\{1,2,\ldots,n\}$. According to Greco's theory, the lower and upper approximation of $Cl_t^{\geq}$ respectively:

$$\underline{apr}_P\left(Cl_t^{\geq}\right)=\bigcup\left\{x\in U: D_P^+(x)\subseteq Cl_t^{\geq}\right\}, \quad (5)$$

$$\overline{apr}_P\left(Cl_t^{\geq}\right)=\bigcup\left\{x\in U: D_P^-(x)\bigcap Cl_t^{\geq}\neq\phi\right\}. \quad (6)$$

$\underline{apr}_P\left(Cl_t^{\geq}\right)$ makes up of all objects of $Cl_t^{\geq}$ set, $\overline{apr}_P$ makes up of all objects of $Cl_t^{\geq}$ set.

The boundary area for $Cl_t^{\geq}$:

$$bnd_P\left(Cl_t^{\geq}\right)=\underline{apr}_P\left(Cl_t^{\geq}\right)-\overline{apr}_P\left(Cl_t^{\geq}\right). \quad (7)$$

Similarly, the lower and upper approximation of $Cl_t^{\leq}$ respectively:

$$\underline{apr}_P\left(Cl_t^{\leq}\right)=\bigcup\left\{x\in U: D_P^-(x)\subseteq Cl_t^{\leq}\right\}, \quad (8)$$

$$\overline{apr}_P\left(Cl_t^{\leq}\right)=\bigcup\left\{x\in U: D_P^+(x)\bigcap Cl_t^{\leq}\neq\phi\right\}. \quad (9)$$

$\underline{apr}_P\left(Cl_t^{\leq}\right)$ is composed by all objects of $Cl_t^{\geq}$, $\overline{apr}_P$ is composed by all objects of $Cl_t^{\leq}$.

The boundary area for $Cl_t^{\leq}$:

$$bnd_P\left(Cl_t^{\leq}\right)=\overline{apr}_P\left(Cl_t^{\leq}\right)-\underline{apr}_P\left(Cl_t^{\leq}\right). \quad (10)$$

The element boundary region of $Cl_t^{\leq}$ or $Cl_t^{\geq}$ cannot explain its ownership.

2.2.3 Classification and reduction

The classification quality of Cl:

$$r_P(Cl)=\frac{\left|U-\left(\left(\bigcup bnd_P\left(Cl_t^{\geq}\right)\right)\bigcup\left(\bigcup bnd_P\left(Cl_t^{\leq}\right)\right)\right)\right|}{|U|}. \quad (11)$$

The $r_P(Cl)$ express ratio of a lot of object attributes in decision table of correct classification number and the total number of object.

The minimal subset $P\in C$, which meet the $r_P(Cl)=r_C(Cl)$ called a reduction of C about Cl, expressed as $red_{Cl}(P)$. A preference decision table may have more than one reduction, the intersection of all reduction called core. The core is the most important attribute preference of attributes in decision table set, it may be empty also.

2.2.4 Preference decision rules

Preference decision rule is a form between conditional preference attributes and decision preference attributes. Based on rough approximation of dominance relation, the preference decision rules in decision table will be derived from the preference information. The decision rule set can be divided into decision classes set $D\geq$ set of decision rules and decision class down and $D\leq$ decision rule set, form decision rules are generated for $D\geq$:

$$f(x,q_1)\geq r_{q1}\wedge f(x,q_2)\geq r_{q2}\ldots\wedge f(x,q_p)\geq r_{qp} \quad then \quad x\in Cl_t^{\geq}. \quad (12)$$

These rules approximate only by the category to the union of $Cl_t^{\geq}$ support.

Form $D \le$ decision rule:

$$f(x,q_1) \le r_{q1} \wedge f(x,q_2) \le r_{q2} \ldots \wedge f(x,q_p) \le r_{qp} \quad then \quad x \in Cl_t^{\le}. \qquad (13)$$

These rules approximate only by the downward and the category $Cl_t^{\le}$ support.

Among them:

$$\{q_1,q_2,\ldots,q_p\} \subseteq C, (r_{q_1},r_{q_2},\ldots,r_{qp}) \in V_{q1} \times V_{q2} \times \ldots \times V_{qp}, t \in \{1,2,\ldots,n\}. \qquad (14)$$

3 Empirical analyses

This paper established the database according to the relevant data in 2012 including 15 index variables of 17 cities in Shandong Province. The data is from the China Statistical Yearbook, China Regional Economic City Economic database. According to the method and steps of processing, it has classified economic development level of the 17 cities of Shandong Province, and derived the decision rules.

3.1 DETERMINE THE INDEX WEIGHT

According to the original data, the method of entropy to calculate the weight of each index

As shown in table 1.

TABLE 1 Regional economic indicator

Index code	Evaluation index	Weight
a1	GDP	0.049
a2	The per capita GDP	0.042
a3	Budgetary revenue of local government	0.071
a4	Budgetary expenditure of local government	0.045
a5	Amount of industrial enterprises	0.059
a6	Gross value of industrial output	0.047
a7	Above scale enterprise product sales taxes and additional	0.159
a8	The total profit above scale enterprises profit	0.063
a9	Total current assets	0.057
a10	Total fixed assets	0.029
a11	Total investment in fixed assets	0.048
a12	Total sales of commodities	0.094
a13	The amount of foreign capital actually used	0.180
a14	Average wages of staff and workers	0.004
a15	The amount of employees at the end of year in the unit	0.052

3.2 ESTABLISH THE KNOWLEDGE REPRESENTATION SYSTEM OF REGIONAL ECONOMIC

According to the index data of different regions, the index will be deal in a discretization way by using SPSS software. Regional economic system can be represented as in table 2.

TABLE 2 Knowledge representation system of regional economic evaluation

U	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	a_{10}	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}
n_1	B	C	B	B	C	C	C	C	B	C	B	B	C	A	A
n_2	A	C	A	A	A	A	A	B	A	B	A	A	A	A	A
n_3	C	C	C	C	B	B	C	B	C	B	C	C	D	B	C
n_4	D	D	D	D	D	D	D	D	D	D	D	D	D	C	D
n_5	C	A	D	D	D	C	A	B	C	A	C	D	D	A	D
n_6	B	C	C	B	B	A	D	A	B	A	A	C	C	B	B
n_7	C	D	C	C	A	B	D	C	B	B	B	C	D	B	B
n_8	C	D	C	C	B	D	D	C	C	B	C	D	D	B	C
n_9	C	D	D	D	D	D	D	D	D	D	C	D	D	C	C
n_{10}	D	B	D	D	D	C	D	D	D	D	C	D	D	C	D
n_{11}	D	D	D	D	D	D	D	D	D	D	D	D	D	B	D
n_{12}	D	D	D	D	D	D	D	D	D	D	D	D	D	B	D
n_{13}	C	D	D	C	B	C	D	D	D	D	C	C	D	C	C
n_{14}	D	D	D	D	B	D	D	D	D	C	C	D	D	D	D
n_{15}	D	D	D	D	C	C	D	D	D	C	D	D	D	D	D
n_{16}	D	D	D	D	D	D	D	D	D	C	D	D	D	C	D
n_{17}	D	D	D	D	C	D	D	D	D	D	D	D	D	D	D

3.3 GENERATE REGIONAL ECONOMIC DECISION TABLE BY USING GREY CLUSTERING AND ROUGH SET METHOD

In this paper, the evaluation order of dominance of regional economic development level given are A>B>C>D, comments V= (1, 8, 15, 31), the indicators are divided into three classes according to the need of practice: The level of regional economic development difference (code 1), the general level of regional economic development (code 2) and the strong level of regional economic development strong class (code 3).

First, determine the grey on the basis of the specific distribution of decision objectives and indicators.

Grey clustering according to the index data, tectonic whitenization weight function as shown in figure 1.

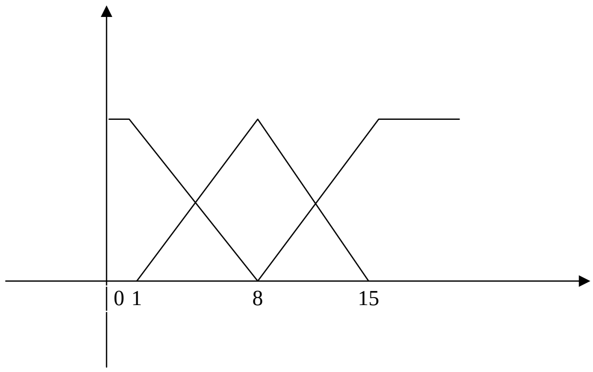

FIGURE 1 Schematic diagram of whitenization weight function

Determine the grey according to the whitenization weight function:

$$f^1=\begin{cases}1, & x\le 1\\ -\dfrac{1}{7}(x-8), & x\in(1,8)\\ 0, & x\ge 8\end{cases}, \quad (15)$$

$$f^2=\begin{cases}0, & x\notin[25,75]\\ \dfrac{1}{25}(x-25), & 25<x<50\\ -\dfrac{1}{25}(x-75) & 50\le x<75\end{cases}, \quad (16)$$

$$f^3=\begin{cases}0, & x<8\\ \dfrac{1}{7}(x-8), & 8\le x<15\\ 1, & x\ge 15\end{cases}. \quad (17)$$

We can get grey clustering coefficient matrix according to the above formula:

$$R=\begin{bmatrix}0.0871396 & 0.5514493 & 0.3614111\\ 0.0006915 & 0.1938554 & 0.8054531\\ 0.1648041 & 0.7437396 & 0.0914563\\ 0.73555 & 0.26445 & 0\\ 0.4129468 & 0.3522875 & 0.2347657\\ 0.1132877 & 0.5622956 & 0.3244167\\ 0.0937004 & 0.8131632 & 0.0931364\\ 0.3421692 & 0.6503078 & 0.0075231\\ 0.581661 & 0.418339 & 0\\ 0.5090344 & 0.4814618 & 0.0095039\\ 0.7747771 & 0.2252229 & 0\\ 0.9287453 & 0.0712547 & 0\\ 0.4324709 & 0.5583343 & 0.0091948\\ 0.6161269 & 0.3838731 & 0\\ 0.6796908 & 0.3203092 & 0\\ 0.635886 & 0.364114 & 0\\ 0.7321114 & 0.2678886 & 0\end{bmatrix}. \quad (18)$$

We can obtain the membership partition table according to the fuzzy clustering coefficient, as shown in table 3.

TABLE 3 Fuzzy membership partition table

U	Fuzzy membership value			The actual decision value
	d_1	d_2	d_3	d
n_1	0.09	0.55	0.36	2
n_2	0	0.19	0.81	3
n_3	0.16	0.75	0.09	2
n_4	0.74	0.26	0	1
n_5	0.41	0.35	0.24	1
n_6	0.11	0.56	0.33	2
n_7	0.09	0.81	0.10	2
n_8	0.35	0.65	0	2
n_9	0.58	0.42	0	1
n_{10}	0.51	0.48	0.01	1
n_{11}	0.77	0.23	0	1
n_{12}	0.93	0.07	0	1
n_{13}	0.43	0.56	0.01	2
n_{14}	0.62	0.38	0	1
n_{15}	0.68	0.32	0	1
n_{16}	0.64	0.36	0	1
n_{17}	0.73	0.27	0	1

We can obtain regional economic knowledge evaluation decision table according to the clustering coefficient matrix, as shown in table 4.

TABLE 4 Regional economic evaluation decision table

U	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	a_{10}	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	d
n_1	B	C	B	B	C	C	C	C	B	C	B	B	C	A	A	2
n_2	A	C	A	A	A	A	A	B	A	B	A	A	A	A	A	3
n_3	C	C	C	C	B	B	C	B	C	B	C	C	D	B	C	2
n_4	D	D	D	D	D	D	D	D	D	D	D	D	D	C	D	1
n_5	C	A	D	D	D	C	A	B	C	A	C	D	D	A	D	1
n_6	B	C	C	B	B	A	D	A	B	A	A	C	C	B	B	2
n_7	C	D	C	C	A	B	D	C	B	B	B	C	D	B	B	2
n_8	C	D	C	C	B	D	D	C	C	B	C	D	D	B	C	2
n_9	C	D	D	D	D	D	D	D	D	D	C	D	D	C	C	1
n_{10}	D	B	D	D	D	C	D	D	D	D	C	D	D	C	D	1
n_{11}	D	D	D	D	D	D	D	D	D	D	D	D	D	B	D	1
n_{12}	D	D	D	D	D	D	D	D	D	D	D	D	D	B	D	1
n_{13}	C	D	D	C	B	C	D	D	D	D	C	C	D	C	C	2
n_{14}	D	D	D	D	B	D	D	D	D	C	C	D	D	D	D	1
n_{15}	D	D	D	D	C	C	D	D	D	C	D	D	D	D	D	1
n_{16}	D	D	D	D	D	D	D	D	D	C	D	D	D	C	D	1
n_{17}	D	D	D	D	C	D	D	D	D	D	D	D	D	D	D	1

3.4 OBTAIN PROBABILISTIC DECISION RULES

We can obtain a reduction by using a rough set attribute reduction algorithm, probabilistic generated by the reduction will determine the rule set, as shown in table 5.

TABLE 5 Probabilistic decision rules

Rule	support	degree of confidence
If GDP <D and Budgetary expenditure of local government $\geq$ B then The economic development level =2	6	100%
If Area GDP $\geq$ D and Budgetary expenditure of local government $\geq$ B then The economic development level =3	1	100%
If Area GDP <D and Budgetary expenditure of local government <B then The economic development level =1	10	100%

As can be found from table 5, the probabilistic decision rules, as a result of deduction, has been generated by adopting the hybrid grey clustering and fuzzy rough sets reduction method. The confidence coefficient was 100% respectively. In addition, for all 17 regions that are correctly classified, the classification qualities of them are 100%. Hybrid model of grey clustering and fuzzy rough set method not only give the relative advantages of categories of the regional economic development level, but obtains probabilistic decision rules which set to minimum, providing a reasonable classification and overall evaluation of the level of regional economic development.

4 Conclusions

This paper is applied to evaluate process of regional economic in the decision-making in accordance with the grey clustering and rough set theory. The results are satisfactory. The generated preference model could deal with many uncertain incompatibilities appearing in the decision table with fewer rules. Due to the preferential model is “if Then” which is a specific preferential probabilistic decision rules. The established preferential model has been closed to the natural inference of the decision makers and could be understand easily. These rules not only explain the preference of decision makers, but also provide decision suggestions.

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