Evaluation of the rural informatization level in the central China based on Catastrophe Progression Method

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Abstract: This paper developed a methodology based on the catastrophe theory for estimating the rural informatization level in central China, and took evaluation of the rural informatization level among the six provinces of central China as an example to test the effectiveness of the method. Taking data from reference and constructing the hierarchy based on catastrophe progression method, it was calculated the scores of rural informatization level among the six provinces of central China using normalizing formula. The results are found to be coincident with practical situation, so it proves the catastrophe progression method works well.

Key words: rural informatization ; level ; evaluation ; Catastrophe Progression Method; the central China

1 Introduction

As rural informatization is an important component of the national informatization development process, it is the basis for decision-making to make an objective assessment and analysis to national and regional level of development of rural informatization.

There have many methods for multiple object comprehensive evaluation [1-4], such as factor analysis, RITE's Index of Information, Information Society Index(ISI), UN's Information Utilization Potentials, fuzzy evaluation, analytic hierarchy process [5] and so on. But some methods have defects with more subjectivity on weight decision or too complex processes in calculation. The paper introduces the main steps and idea of a method using catastrophe theory (CT), namely, called catastrophe progression method (CPM). Its characteristic is combining catastrophe theory with fuzzy mathematics, and only considers the relative importance of the indices, so the method avoids the subjectivity for weight decision. Catastrophe progression method also has advantages in solving problems of fuzzy multiple object decision because the catastrophe progression is a multidimensional fuzzy membership function. With these characteristics, the method is easier and the results are more precise [6].

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2 The evaluation methodology for the rural informatization level in central China

2.1 Evaluation index system of the rural informatization level

According as the composition project of national informatization index issued by Information & Industry Ministry of China on July 29th, 2001, taking the literature [7] from reference, this paper presents the evaluation index system for the rural informatization level in the central China, which includes the 5 categories (secondary indices) of the Economic strength, Information infrastructure, Information terminal equipment, Human resource and Information utilization, and 14 tertiary indices (Table 1).

Table 1. Evaluation index system for the rural informatization level in the central China.

Evaluation objective	Category	Indices	Index abbreviation
informatization level of rural areas	Economic strength	GDP per capita	GDP
		Revenue per capita	RP
		Per capita income of rural households	PI
	Information infrastructure	Long-distance telephone exchange capacity	TC
		Mobile switching capacity	MC
		Length of long-distance optical cable	OC
		Internet broadband access ports	IB
	Information terminal equipment	Color television ownership	TO
		Computer ownership	CO
		Mobile telephone ownership	MO
	Human resource	Percentage of literate population to total aged 15 and over	LP
		Number of rural information service employees	IEm
	Information utilization	Proportion of per capita information consumption expenditure of rural households	IEx
		Proportion of Internet users in rural areas	IU

2.2 Assessment model of the rural informatization level

Establishment of the hierarchical structural model. According to the regulation of indices grouping aforementioned, we constructed the catastrophe progression model for informatization level of rural areas in central China by four hierarchies, which was broken down in a manner as shown in Fig.1.

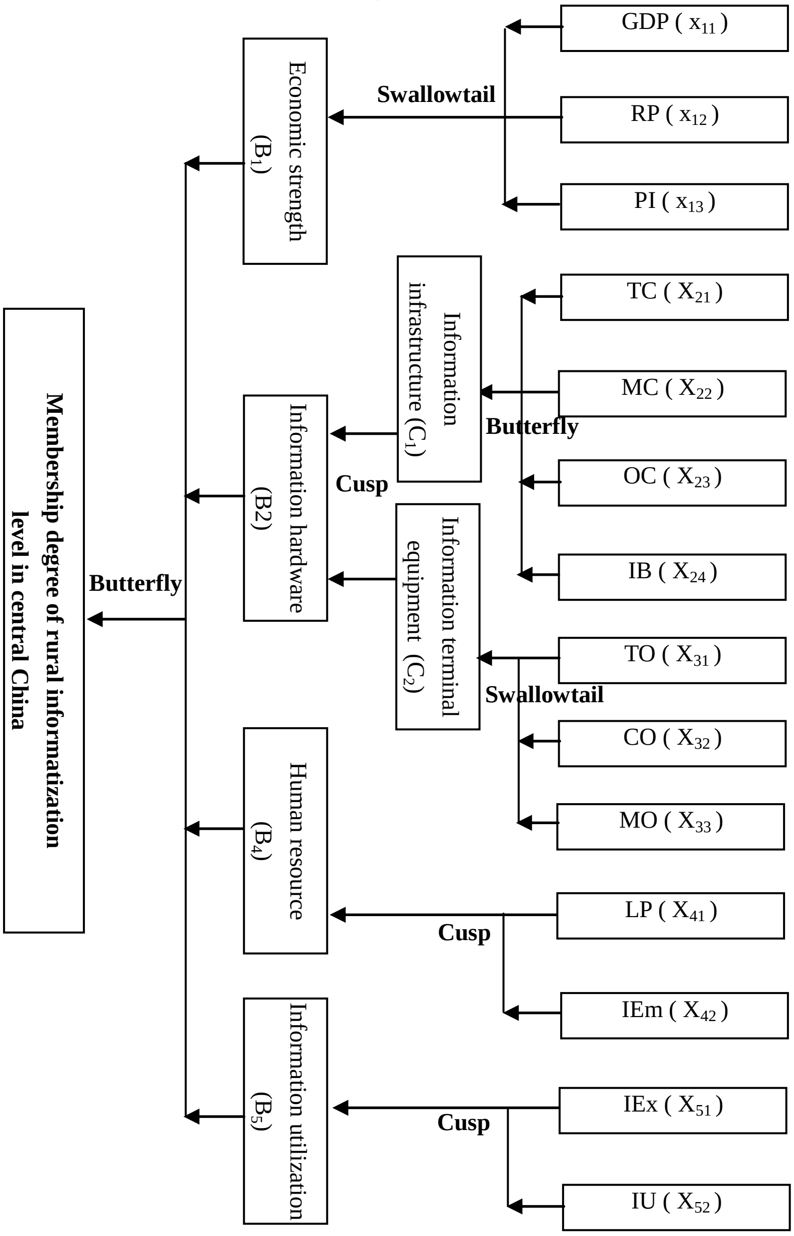

Fig.1. Catastrophe progression model for rural informatization level in the central China.

Confirming the catastrophe type in every catastrophe subordinate system. Catastrophe theory analyses critical degenerate points of the potential function, where not just the first derivative, but one or more higher derivatives of the potential function are also zero. There are seven fundamental types of Catastrophe models presented，three types of which, such as elliptic umbilic catastrophe, hyperbolic umbilic catastrophe, and parabolic umbilic catastrophe, are under behavior variation of two dimension. Among seven fundamental types，only four common catastrophe types are cusp catastrophe, swallowtail catastrophe and butterfly catastrophe, respectively, which potential functions are as follows [8]:

Fold catastrophe: $f(x) = x^3 + ax$.

Cusp catastrophe: $f(x) = x^4 + ax^2 + bx$.

Swallowtail catastrophe: $f(x) = \frac{1}{5}x^5 + \frac{1}{3}ax^3 + \frac{1}{2}bx^2 + cx$.

Butterfly catastrophe: $f(x) = \frac{1}{6}x^6 + \frac{1}{4}ax^4 + \frac{1}{3}bx^3 + \frac{1}{2}cx^2 + dx$.

Where f(x) is the potential function of the state variable x, and a, b, c and d are control variables of the state variable.

In the catastrophe progression model for informatization level assessment of rural areas, the catastrophe type was confirmed in every evaluation index layer (see Fig.1). There were three catastrophe type, such as cusp catastrophe (one index divided into two sub-indices), swallowtail catastrophe (into three sub-indices) and butterfly catastrophe (into four sub-indices).

Normalizing the control variables of the catastrophe model

Standardizing data. The standardized data are in the value range of from 0 to1. Equation (1) is adopted if the index is positive, equation (2) is applied if negative.

a) For The-Larger-The-Better indices, let

$$y_{ij} = \frac{x_{ij} - x_{\min(j)}}{x_{\max(j)} - x_{\min(j)}} \qquad x_{\min(j)} < x_{ij} < x_{\max(j)} \tag{1}$$

b) For The-Smaller-The-Better indices, let

$$y_{ij} = \frac{x_{\max(j)} - x_{ij}}{x_{\max(j)} - x_{\min(j)}} \qquad x_{\min(j)} < x_{ij} < x_{\max(j)} \tag{2}$$

Where j is a sequence number for catastrophe subordinate systems, i is a serial number of control variables in a catastrophe subordinate system; x_{ij} is merely the values of x corresponding to control variables in a hierarchy of i and j, respectively; y_{ij} is only the standard transformation values of x_{ij}; $x_{\min(j)}$, $x_{\max(j)}$ are lower limit or upper limit values of x corresponding to control variables in a catastrophe subordinate system, respectively.

Formulas for normalization of control variables. For the cusp, fold, swallowtail, and butterfly catastrophe system, the decomposition forms of the equation of the bifurcation point set and the normalization formulas are showed in Table 2.

Table 2. Catastrophe models under behavior variation of one dimension.

Catastrophe type	Dimensions of control variation	Potential function	Bifurcation set	Normalization formula
Fold	1	$f(x)=x^3+ax$	$a=-3x^2$	$x_a=\sqrt{a}$
Cusp	2	$f(x)=x^4+ax^2+bx$	$a=-6x^2,b=8x^3$	$x_a=\sqrt{a},x_b=\sqrt[3]{b}$
Swallowtail	3	$f(x)=\frac{1}{5}x^5+\frac{1}{3}ax^3$ $+\frac{1}{2}bx^2+cx$	$a=-6x^2,b=8x^3,$ $c=-3x^4$	$x_a=\sqrt{a},x_b=\sqrt[3]{b},$ $x_c=\sqrt[4]{c}$
Butterfly	4	$f(x)=\frac{1}{6}x^6+\frac{1}{4}ax^4+\frac{1}{3}bx^3$ $+\frac{1}{2}cx^2+dx$	$a=-10x^2,b=20x^3,$ $c=-15x^4,d=4x^5$	$x_a=\sqrt{a},x_b=\sqrt[3]{b},$ $x_c=\sqrt[4]{c},x_d=\sqrt[5]{d}$

Principles of finding values of catastrophe subordinate functions. During the process of computation, we must follow two principles, i.e., a complementary and a non-complementary principle. The non-complementary principle means that the smallest of the state variable values corresponding to the control variables (x_a, x_b, x_c and x_d) is chosen as the state variable value of the whole system; However, the complementary principle implies $x=(x_a+x_b+x_c+x_d)/4$. Hierarchically doing the calculation in the same way, the value of the overall catastrophe subordinate function can be found [9].

3 Results and discussion

In the light of the evaluation methodology of rural informatization level aforementioned, the paper take evaluation of rural informatization level among the six provinces of central China as an example to test the effectiveness of the Catastrophe Progression Method， and referred to interrelated data on Beijing and nationally average in the mainland of China.

The central China is a central region, including six provinces, such as Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan (see Fig.2), with total population of 360 million people in the end of 2008. It plays an important role on the pattern of economic and social development in China, which land area is 1.03 million square kilometers, Gross Regional Product of which reached 6.3188 trillion RMB Yuan in 2008, accounting for 19.3% of GDP in China.

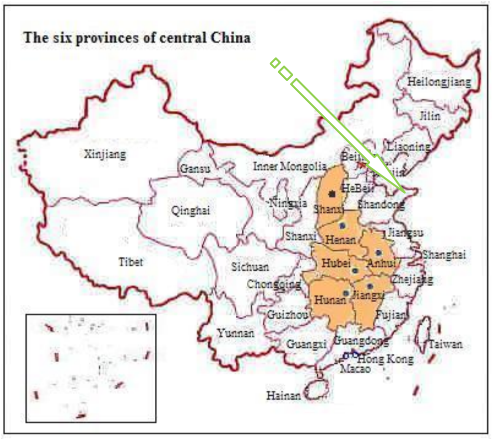

Fig.2. Space diagram of the six provinces of central China.

Taking data from reference [7], the region′s overall number of communication facilities was in place of four indices of information infrastructure in rural areas, telecommunications and other information transfer service employees in place of indices about the number of rural information service personnel, the proportion of local comprehensive internet users in place of the proportion of internet users in rural areas.

Table 3 showed some practical index values of the rural informatization level among the six provinces of central in 2006, Table 4 showed the standardized data of practical index values for the rural informatization level from the six provinces of central China transformed by equations (1) and (2). At the same time, the scores of rural informatization level among the six provinces of central China were calculated using normalizing formula (see Table 5).

Table 3. Collected data from the six provinces of central China [7].

Region	x_{11}	x_{12}	x_{13}	X_{21}	X_{22}	X_{23}	X_{24}	X_{31}	X_{32}	X_{33}	X_{41}	X_{42}	X_{51}	X_{52}
Beijing	4.98	7066.0	8275	365	129	1788	21	133.2	36.1	104.3	95.5	37.6	1542.2	30.4
Shanxi	1.41	1729	3181	86.2	43.2	1445	4.4	98.4	1.38	72.1	95.6	9.8	564	11.3
Anhui	1.01	701	2969	78.5	23.7	1873	2.2	91.8	1.16	79.2	83.7	4.4	527.9	5.5
Jiangxi	1.08	704	3460	108.0	40.3	1052	2.8	90.0	1.10	64.7	90.8	5.9	538.4	6.6
Henan	1.33	723	3261	62.4	31.3	1764	2.5	88.8	1.02	53.4	91.4	4.3	419.4	5.5
Hubei	1.33	836	3419	82.1	44.7	1234	3.9	92.1	2.33	57.3	90.2	8.6	538.4	9.3
Hunan	1.19	754	3390	73.4	31.7	1393	3.3	80.9	0.95	60.2	93.5	5.3	591.4	6.4
Nationally average	1.79	1417	3587	106.8	47.3	752	5.02	89.4	2.7	62.5	90.69	7.4	593.9	10.5

Data source: Huang, 2009.

Table 4. Standardized data from the six provinces of central China.

Region	x_{11}	x_{12}	x_{13}	X_{21}	X_{22}	X_{23}	X_{24}	X_{31}	X_{32}	X_{33}	X_{41}	X_{42}	X_{51}	X_{52}
Beijing	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Shanxi	0.101	0.162	0.040	0.079	0.185	0.669	0.117	0.335	0.012	0.367	1.008	0.165	0.129	0.233
Anhui	0.000	0.000	0.000	0.053	0.000	1.082	0.000	0.208	0.006	0.507	0.000	0.003	0.097	0.000
Jiangxi	0.018	0.000	0.093	0.151	0.158	0.290	0.032	0.174	0.004	0.222	0.602	0.048	0.106	0.044
Henan	0.081	0.003	0.055	0.000	0.072	0.977	0.016	0.151	0.002	0.000	0.653	0.000	0.000	0.000
Hubei	0.081	0.021	0.085	0.065	0.199	0.465	0.090	0.214	0.039	0.077	0.551	0.129	0.106	0.153
Hunan	0.045	0.008	0.079	0.036	0.076	0.619	0.059	0.000	0.000	0.134	0.831	0.030	0.153	0.036
Nationally average	0.196	0.112	0.116	0.147	0.224	0.000	0.150	0.163	0.050	0.179	0.592	0.093	0.155	0.201

Table 5 showed catastrophe progression values of the rural informatization level among the six provinces in central China. From Table 5, catastrophe progression values (CPV) of the rural informatization level averaged 0.793 in the mainland of China; CPV is bigger in only one province of the six provinces in the central China than nationally average in the mainland of China. CPV is larger in Beijing Municipality than in each region of the six provinces in the central China. Among the six provinces in the central China, CPV of Shanxi province is first with 0.800, Hubei province second with 0.773, Jiangxi province third with 0.722, Hunan province fourth with 0.714, Henan province and Anhui province least with 0.354 and 0.222, respectively. The results are found to be coincident with practical situation.

Table 5. The evaluation result by CPM.

Region	Catastrophe progression values	No.	Region	Catastrophe progression values	No.
Beijing	1.000		Henan	0.354	5

Shanxi	0.800	1	Hubei	0.773	2
Anhui	0.222	6	Hunan	0.714	4
Jiangxi	0.722	3	Nationally average	0.793	

4 Conclusion

The paper take evaluation of rural informatization level among the six provinces of central China as an example to verify the effectiveness of the method. Based on catastrophe progression method, it calculated the scores of rural informatization level among the six provinces of central China using normalizing formula. The results are found to be coincident with practical situation, so it proves the catastrophe progression method works well.

From the calculation process, it was found that catastrophe progression method works simply and quickly. So the method was proved feasible in practice and provides us a new way in solving the problems of multiple objects comprehensive evaluation [6].

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