A New Data Mining Approach Combined with Extension Set and Rough Set

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***Abstract*—Extension data mining is a product combining extenics with data mining. Establishing the extenics provides a new idea and method for data mining and opens up a new research direction for data mining. Using the extenics method of combining the data mining technology not only can access to static knowledge, but also can dig to realization of knowledge. By using the theory and method of Extenics, it can mine the knowledge from database which is relative to solve contradictory problems. And the knowledge includes the extension classification knowledge, conductive knowledge and other knowledge associated with transformation, which collectively called extension knowledge. Extension data mining can play a role in classification transformation, finding the root causes of the problem, identifying potential transformation knowledge. Finally, how to tap new customers and how to recommend an appropriate brand to new customers, Research results indicate that extension data mining can provide effective support for decision-making of enterprise.**

***Index Terms*— extenics, rough set, extension data mining (EDM), attributes reduction**

I. INTRODUCTION

Extenics [1] studies the theories and methods of innovation and has become the theoretical foundation and method source for innovation and creation. The research objective of Exenics is contradictory problems. Its basic theory is Extension Theory, its method system is Extension Method, and its basic logic is Extension Logic. And the integration of Extenics with other fields formed the Extension Engineering. Extenics is made up of Extension Theory, Extension Innovative Method and Extension Engineering

Data mining [2-4] is the process of analyzing data from different perspectives and summarizing it into useful information that can be used to increase revenue, cuts costs. Data mining software is one of a number of analytical tools for analyzing data. It allows users to analyze data from many different dimensions or angles, categorize it, and summarize the relationships identified. Technically, data mining is the process of finding correlations or patterns among dozens of fields in large relational databases. Companies have used powerful computers to sift through volumes of supermarket scanner data and analyze market research reports for years. However, continuous innovations in computer processing power, disk storage, and statistical software are dramatically increasing the accuracy of analysis while driving down the cost [5-7].

Matter-element is the logic cell of extenics and puts the matter, the characteristics and their measure together into consideration. Extension data mining (EDM) [8] is a product combining Extenics with data mining. Extension data mining was proposed in 2004. After several years' researching and exploring, we finally have clarified the object and objective of this study. By using the theory and method of Extenics, it can mine the knowledge from database which is relative to solve contradictory problems. And the knowledge includes the Extension classification knowledge, conductive knowledge and other knowledge associated with transformation, which collectively called Extension knowledge. At present, we preliminary explored some questions of EDM, just the basic theory, basic method and their implementation on computers.

In this paper, reducing the condition attributes based on the matter-element theory and rough set method, calculating the importance to the decision attribute for each condition attribute after reduction, and data mining the relevant rules based on the reduced attributes, extension relevant function is used to depict quality of data gather in data mining. Extension data mining has advantage in the decision-making of the enterprise. Extension relevant function can be used to quantitatively depict data gather of data mining. It can effectively solve the problem of the data quality, and provide clear decision-making for the enterprise. It also can provide a new thinking mode and approach for data mining which extenics is applied in.

II. BASIC CONCEPTION

1) Rough Sets

Rough sets theory, a mathematical theory for data analysis, was first introduced by Z. Pawlak in 1982. Defining knowledge from a new perspective, it can be

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used to solve uncertain and imprecise problems. The most special characteristic of this theory is that it doesn't need any previous or extra information to tackle questions except for the necessary data muster. In combination with neural network, expert system, fuzzy theory, evidence theory, and genetic algorithm, rough sets theory is widely used in various fields, such as knowledge acquirement, data mining, pattern recognition, machine learning, and decision support. As an important component of rough sets theory, reduction of attributes attracts increasing attention in both theory and application. Reduction of attributes is relative to problems on selecting subsets of attributes in machine learning. It can effectively reduce information redundancy, and help people make correct and concise decisions. In attributes redcuction, the reduction of information system is usually not unique. The attributes number directly affects the coding length of decision rules. To acquire the most concise decision rules, a reduction with minimal attribute is required. However, Wong and Ziarko[9] have proved that the minimal reduction in an information system is a difficult problem, so recently there is no efficient algorithmfor finding an optimal reduction[10].

2) Extension Set

In contrast to the crisp set, the fuzzy set allows for the description of concepts with boundary which is not explicit. It concerns not only whether an element belongs to the set but also what degree it belongs. The range of membership function is [0, 1] in fuzzy set. The extension set extends the fuzzy set from [0, 1] to [-∞, +∞]. It means that an element belongs to any extension set to a different degree. Define the membership function as $k(x)$ to represent the degree of an element belonging to a set. A degree between zero and one corresponds to the normal fuzzy set. When $k(x) < 0$, it describes the degree to x not belonging to a set, which is not defined in a fuzzy set. When $-1 < k(x) < 0$, it means that the element x still has a better chance to be included into the set if the set is adjusted. $k(x) < -1$ implies that the element x has no chance to be contained into the set,which also represent the degree of an element not belonging to a set. The extension theory tries to solve incompatibility and contradiction problems by transformation of the matter element.

(1) Definition of matter-element

Defining the name of a matter as O, one of the characteristics of the matter as c and the value of c as v, a matter-element in extension theory can be described as follow:

$$M = (O, c, v) \quad \text{Eq. (1)}$$

Where O, c and v are called the three fundamental elements of the matter-element. For example, M = (Tang, Weight, 60 kg) can be used to state that Tang's weight is 60 kg. If the value of the characteristic has a classical domain or an interval, we define the matter-element for the classical domain as follows:

$$M = (O, c, v) = (o, c, \langle v^l, v^u \rangle) \quad \text{Eq. (2)}$$

Where v^l and v^u are the lower bound and upper bound of a classical domain.

(2) Multi-dimensional matter-element

Assuming $M = (O, c, v)$ a multi-dimensional ?

matter-element, $c = [c_1, c_2 ..., c_n]$ a characteristic vector and $v = [v_1, v_2 ..., v_n]$ a value vector of c, then a multi-dimensional matter-element is defined as where

$$M = (O, c, v) = \begin{bmatrix} O & c_1 & v_1 \\ & c_2 & v_2 \\ & \vdots & \vdots \\ & c_n & v_n \end{bmatrix} = \begin{bmatrix} M_1 \\ M_2 \\ \vdots \\ M_n \end{bmatrix} \quad \text{Eq. (3)}$$

3) Divergence of Matter-element

A matter may have many characteristics. The same characteristics and values may also belong to some other matters. In extension theory, there are some formulations to express these points as follows:?

4) Definition of Extension set

Let U be the universe of discourse; x the discretional element in U, is a mapping from U to real number field R; $T = (T_U, T_k, T_x)$ is a given extension transformation.

The $k(x)$ maps each element of U to a membership grade between $-\infty$ and ∞.The higher the degree, the more the element belongs to the set. In a special condition, when $0 < k(x) < 1$, it corresponds to a normal fuzzy set. $k(x) < -1$ implies that the element x has no chance to belong to the set.

$$\widetilde{E}(T) = \{(x, y, y') \mid x \in T_U U, y = k(x) \in R, y' = T_k k(T_x x) \in R\} \quad \text{Eq. (4)}$$

is called an extensible set in U. $y = k(x)$ is a dependent function of $\widetilde{E}(T)$. $y' = T_k k(T_x x)$ is an extension function of $\widetilde{E}(T)$,among which T_U is the transformation of U, T_k the transformation of the dependent function and T_x the transformation of element x.

When $-1 < k(x) < 0$, it is called an extension domain, which means that the element x still has a chance to become part of the set.

5) Definition of Distance

If $X_0 = \langle a, b \rangle$ and $X = \langle c, d \rangle$ are two intervals in the

real number field, and $X_0 \subset X$, then the correlation function in the extension theory can be defined asfollows:

$$k(x) = \begin{cases} \dfrac{\rho(x, X_0)}{D(x, X_0, X)} - 1, & \rho(x, X_0) = \rho(x, X) \\ & and\ x \notin X_0 \\ \dfrac{\rho(x, X_0)}{D(x, X_0, X)} & others \end{cases}$$

Eq. (5)

Where

$$D(x, X_0, X) = \begin{cases} \rho(x, X) - \rho(x, X_0) & \rho(x, X) \neq \rho(x, X_0), x \notin X_0 \\ \rho(x, X) - \rho(x, X_0) + a - b & \rho(x, X) \neq \rho(x, X_0), x \in X_0 \\ a - b & \rho(x, X) = \rho(x, X_0) \end{cases}$$

Eq. (8)

$$\rho(x, X_0) = | x - \frac{a+b}{2} | - \frac{b-a}{2}$$ Eq. (6)

$$\rho(x, X) = | x - \frac{c+d}{2} | - \frac{d-c}{2}$$ Eq. (7)

The correlation function can be used to calculate the membership grade between x and X as shown in Fig. 1. When $k(x) > 0$, it indicates the degrees to which x belongs to X_0.

When $k(x) < 0$, it describes the degree to which x does not belong to X_0, which is not defined in fuzzy set theory. When $-1 < k(x) < 0$, it is called the extension domain, which means that the element x still has a chance to become part of the set if conditions change.

III. Extension Data Mining base on Rough Set

1) *Attribute Reduction based on Rough Set*

We often encounter problems whether we can remove some data from a data table preserving its basic properties, i.e. whether a table contains some superfluous data.

Thus a reduct is a set of attributes that preserves partition. It means that a reduct is the minimal subset of attributes that enables the same classification of elements of the universe as the whole set of attributes. In other words, attributes that do not belong to a reduct are superfluous with regard to classification of elements of the universe.

Reducts have several important properties.Next we will present two of them. First, we define core attributes of a notion. Let B be a subset of A. The core of B is the set with all indispensable attributes of B. The followed is an important property, connecting the notion of the core and reducts

$$Core(B) = \bigcap Red(B),$$ Eq. (9)

where Red(B) is the set with all reducts of B.

Because the core is the intersection of all reducts, it is included in every reduct, i.e., each element of the core belongs to some reduct. Thus, in a sense, the core is the most important subset of attributes, for none of its elements can be removed without affecting the classification power of attributes.

To further simplify an information table we can eliminate some values of attribute from the table in such way and we are still able to discern objects in the table as the original one. To this end we can apply similar procedure to eliminate superfluous attributes, which is defined as follows.

The set of all indispensable values of attributes in B for x will be called the value core of B for x, and will be denoted as $CORE^x(B)$.

Also in this case we have

$$CORE^x(B) = \bigcap Red^x(B)$$ Eq. (10)

where $Red^x(B)$ is the family of all reducts of B for x.

Suppose a dependency C ⇒D, the set D may not depends on the whole set C but on its subset C' , therefore we might be interested to find this subset. In order to solve this problem we need the notion of a relative reduct, which will be defined and discussed next.

Let C,D ⊆ A. Obviously if C' ⊆ C is a D-reduct of C, then C' is a minimal subset of C such that

$$\gamma(C, D) = \gamma(C', D).$$ Eq. (11)

- We will say that attribute a∈C is D-dispensable in C, if $POS_C(D) = POS_{(C-\{a\})}(D)$; otherwise the attribute a is D-indispensable in C.
- If all attributes a∈C are C-indispensable in C, then C will be called D-independent.
- Subset C' ⊆ C is a D-reduct of C, iff C' is D-independent and $POS_C(D) = POS_{C'}(D)$.

The set of all D-indispensable attributes in C will be called D-core of C, and will be denoted by $CORE_D(C)$. In this case we also have the property

$$CORE_D(C) = \bigcap Red_D(C)$$ Eq. (12)

where $Red_D(C)$ is the family of all D-reducts of C.

If D = C we will get the previous definitions.

$$IND(R) = IND(R - \{r\}) \quad \text{Eq. (13)}$$

Where ind ( ) denotes the indiscernibility relation, and r ∈R, which is the attribute sets. Obviously, if Eq. (23) holds, r is the redundant attribute element to describe the knowledge base characterized by attribute sets R. As a result, r can be removed from R, which is so-called knowledge simplification related to the classification problem. Moreover, the simplified attribute sets ind (R) is equivalent to the original attribute sets R, so some attributes can be reduced from the original table.

2) Extension Relevant Rule

Relevant rule is defined that certain cases can bring about others cases. Such as rule $X \Rightarrow Y$, X and Y are the attribute variables in database. Extension relevant rule with matter-element is $\wedge_{i=1}^{n} r_i \Rightarrow (l)R$ .Relevant rules with combined type have essence-element item and extension transform item. It is $r_1 \wedge r_2 \wedge \cdots \wedge r_n \Rightarrow (l)R$. Relevant rule with combined type is fit for researching relevant rule of complicated system.

3) Decide Classical Field and Modulation Field

According to every characteristic variable, its data range can be acquired. Consequently classical field and modulation field of different levels, which is correlative with each characteristic, will be ensured.

$$M_{cf} = (O_{cf}, c, v) = \begin{bmatrix} O_{cf} & C_1 & \langle v_{cf1}^l, v_{cf1}^h \rangle \\ & C_2 & \langle v_{cf2}^l, v_{cf2}^h \rangle \\ & \vdots & \vdots \\ & C_n & \langle v_{cfn}^l, v_{cfn}^h \rangle \end{bmatrix} \quad \text{Eq. (14)}$$

where O_{cf} expresses different levels. $c_i(i = 1,2,\cdots,n)$ expresses the characteristic of O_{cf} . v_{cf} is the variable range ensured by characteristic variables $c_i(i = 1,2,\cdots,n)$ of O_{cf} .So v_{cf} is called $\langle v_{cfi}^l, v_{cfi}^h \rangle (i = 1,2,\cdots,n)$ which is a classical field. This is similar to $X_0 = \langle a, b \rangle$.

$$M_{mf} = (O_{mf}, c, v) = \begin{bmatrix} O_{mf} & C_1 & \langle v_{mf1}^l, v_{mf1}^h \rangle \\ & C_2 & \langle v_{mf2}^l, v_{mf2}^h \rangle \\ & \vdots & \vdots \\ & C_n & \langle v_{mfn}^l, v_{mfn}^h \rangle \end{bmatrix} \quad \text{Eq. (15)}$$

v_{mf} is the variable range ensured by characteristic variables of O_{mf} .So v_{mf} is called $\langle v_{mfi}^l, v_{mfi}^h \rangle (i = 1,2,\cdots,n)$ which is a modulation field. This is similar to $X = \langle c, d \rangle$.

4) Compute Relevant Degree according to Relevant Function

Let $I_i(i = 1,2,\cdots m)$ be the subsets of the extension set O , $I_i \subset O, (i = 1,2,\cdots,m)$ To any testing object $p \in P$, using the following steps to determine whether p belongs to the certain subset I_i ,and calculates the dependent degree.

Where $c_i(i = 1,2,\cdots,n)$ are n different characteristics of I_i ,and v_{cf} are the range of $c_i(i = 1,2,\cdots,n)$ associated with subset $I_i(i = 1,2,\cdots m)$

Based on the analysis of characteristic variables, relevant function can be expressed as follows:

Relevant degree of the identified object O about the $j(j = 1,2,\cdots,m)$ level is:

$$k_{ij} = \sum_{i=1}^{n} \alpha_{ij} \cdot \frac{k_j(x_i)}{\max|k_j(x_i)|}, \quad i = 1,2,\cdots n; j = 1,2,\cdots m \quad \text{Eq. (16)}$$

$$k_i = \vee_{j=1}^{m} k_{ij} \quad \text{Eq. (17)}$$

α is Right weighted value. Determine the weighted value of each characteristic and calculate the value of dependent function. Here we introduce the proportion of the weighted value of each characteristic, calculated as:

$$\alpha_{ij} = \frac{x_j / b_{ij}}{\sum_{j=1}^{m} x_j / b_{ij}} \quad \text{Eq. (18)}$$

Finally, we determine the category of the testing sample. If $k_i = \max k_{ij} \quad j = 1,2,\cdots,m$,It means the testing sample belongs to I_i .If $k_i \le 0 \quad j = 1,2,\cdots,m$ is right for any j , it means the testing sample is not belonging to any category that you have divided.

IV. APPLICATION

China Mobile's current brands are Quanqiu tong, Shenzhou xing and Donggan didai. How to tap new customers and how to recommend an appropriate brand to new customers? Their choices are Quanqiu tong, Shenzhou xing and Donggan didai, or others?

1) Acquire and Deal with Data

There are four factors affecting the choices of the new customers,age, basic telephone expenses, message charge and GRPS charge. The value of above four factors can be acquired from survey of related groups. This paper analyses the data of the survey from more than 1000 customers, as shown in Table 1.

TABLE 1.
DATA COLLECTION

customer	age	basic telephone expenses (Yuan/per month)	message expensis	GRPS expensis	the brand
1	20	80	20	50	Donggan didai
2	45	400	2	5	Quanqiu tong
3	22	100	20	20	Donggan didai
4	45	1000	5	20	Quanqiu tong
5	18	60	20	20	Donggan didai
6	30	100	5	15	Shenzhou xing
7	32	500	2	5	Shenzhou xing
8	30	480	3	6	Shenzhou xing
…	…	…	…	…	…
amount to 1000 data					

According to Table 1, we can derive a new table 2 after attributes reduction based on rough set. The attribute age can be reduced to derive Table 1.

TABLE 2.
DATA COLLECTION AFTER ATTRIBUTES REDUCTION BASED ON ROUGH SET

customer	basic call charge(Yuan/per month)	message charge	GRPS charge	the brand
1	3	4	3	3
2	2	1	1	1
3	3	4	2	3
4	1	2	2	1
5	4	4	2	3
6	3	2	2	2
7	2	1	1	2
8	30	480	3	6
…	…	…	…	…

Data in Table 2 is fuzzed by the precision in fuzzy control. The theory field, which shows the level of the survey, can be acquired, as shown in Table 3 and Table 4.

TABLE3.
CLASSICAL FIELD OF FACTORS

the brand	age	basic call charge(Yuan/per month)	message charge	GRPS charge
Donggan didai	15-25	5-50	5-10	0-20
Quanqiu tong	25-50	200-500	0-10	0-50
Shenzhou xing	20-40	20-200	0-5	0-20

TABLE4.
MODULATION FIELD OF FACTORS

the brand	age	basic call charge(yuan/per month)	message charge	GRPS charge
Donggan didai	15-40	0-200	5-50	0-200
Quanqiu tong	20-70	100-2000	0-50	0-500
Shenzhou xing	15-60	0-500	0-20	0-200

2) Decide Right Coefficient

When an object is evaluated, there are varying degree of standard. Right coefficient can indicate the degree of the standard. Right coefficient has important effect on the evaluation result.

$$U/R = \{1,(2,7),3,4,5,6\},$$
$$U/\{R-A\} = \{1,(2,7),3,(4,6),5\}$$
$$U/\{R-B\} = \{1,(2,7),(3,6),4,5\},$$
$$U/\{R-C\} = \{(1,3),(2,7),4,5,6\}$$
$$U/S = \{(1,3,5),(2,4),(6,7)\},$$
$$\mu_R(S) = \{1,3,4,5,6\} + \{2,7\}i,$$
$$\mu_{R-A}(S) = \{1,3,5\} + \{2,4,6,7\},$$
$$\mu_{R-B}(S) = \{1,4,5\} + \{2,3,6,7\}i,$$
$$\mu_{R-C}(S) = \{4,5,6\} + \{1,2,3,7\},$$
$$k = \gamma(R,D) = 5/7,$$
$$\gamma(R-A,D) = \gamma(R-B,D) = \gamma(R-C,D) = 3/7$$
$$\therefore \quad \alpha_A = \alpha_B = \alpha_C = 0.333$$

Therefore, there are four factors from important to unimportant. The sequence is t age, basic call charge, message charge and GRPS charge. According to $\beta_a = 0.4, \beta_b = 0.3, \beta_c = 0.3$,

$\omega_i = 0.6 \times \alpha_i + 0.4 \times \beta_i$,Then we decide right coefficient $\alpha = (0.36, 0.32, 0.32)$

3) Acquire Object

According to the demand of the new customers, the china Mobile selects person A and B as objects. The value of each factor is acquired from two people. Then matter-element model of object is shown as follows.

$$M_A = \begin{bmatrix} O_A & age & 20 \\ & basic\ call\ charge & 50 \\ & message\ charge & 20 \\ & GPRS\ charge & 10 \end{bmatrix}$$

$$M_B = \begin{bmatrix} O_B & age & 40 \\ & basic\ call\ charge & 500 \\ & message\ charge & 20 \\ & GPRS\ charge & 100 \end{bmatrix}$$

According to Eq. (5) ,Eq. (6) ,Eq. (7) and Eq. (8), We can derive Table 5 and Table 6.

TABLE 5.
RELEVANT DEGREE OF PERSON A

	k1	k2	k3
Donggan didai	-0.222	-0.067	-0.213
Quanqiu tong	-0.896	-0.289	-0.067
Shenzhou xing	-0.632	-0.289	-0.022

TABLE 6.
RELEVANT DEGREE OF PERSON B

	k1	k2	k3
Donggan didai	-0.326	-0.778	-0.867
Quanqiu tong	0.2	-0.02	0.2
Shenzhou xing	-0.221	-0.02	-0.2

Characteristic variables of objects are computed by using extension relevant function. The experiment result is expressed as Table 7

TABLE 7.
THE RESULT OF THE RELEVANT DEGREE.

person	Quanqiu tong	Donggan didai	Shenzhou xing	result
A	-0.2926	0.4845	-0.3742	Donggan didai
B	0.5483	-0.1048	0.2425	Quanqiu tong

From analysis in Table7, it describes that person A belongs to the level of Donggan didai and person B belongs to the level of Quanqiu tong . The analysis result can provide effective support for china Mobile to recommend an appropriate brand to new customers.

V. CONCLUSION

Extension data mining has advantage in the decision-making of the enterprise. Extension relevant function can be used to quantitatively depict data gather of data mining. It can effectively solve the problem of the data quality, and provide clear decision-making for the enterprise.

At present, in the extension data mining area, from the standpoint of extension theory, methods, algorithms, applications, technical improvements, some experts have studied the existed data mining problems mentioned above by using the Extension principles and methods and achieved some achievements. With in-depth study and strengthen research efforts, there will be research results with a greater application value. The knowledge-based economy has greatly accelerated the pace of economic globalization. The ever-changing environment shortens the information's and knowledge's update cycle. So innovation and resolving contradictory problems have become an increasingly important work of all kinds of occupations. Therefore, how to mine transforming knowledge has become an important task of researching data mining. At present, studying object of extension data mining has its limit in relational database or data warehouse. In fact, when studying text, image and video data, web data and so on, we should also consider the effect of transformation on data. And these are also the study area of extension data mining.

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