Application of Ranking Model to Energy Evaluation Based on Dominance Relation

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Abstract: In the rapid social development and energy shortage period, the correct evaluation of the energy appears to be very necessary. Build dominance relation of energy evaluation based on rough sets theory, put up with a new dominance degree metric method after analysing the defects of the existing ranking model, apply the ranking model to energy evaluation, the results show that it can objectively evaluate the advantages and disadvantages of the given energy, which match the actual situation and our subjective perception, the ranking model provide a new idea and method for multi-attribute decision making problems.

Keywords: Dominance relation; dominance class; dominance matrix; banking model; energy evaluation

1 Introduction

The term “energy” has aroused strong concern since the two oil crises, as the basic driving force of economic growth, energy is essential to the development of the national economy. In the era of rapid development of economic, how to develop and use the energy reasonably and effectively in order to safeguard the sustainable development of society, is becoming an issue must be considered for all the countries to develop their development strategic policy. Therefore, making the evaluation of energy scientific and rational becomes the basis of the proper use of energy.

Current energy evaluation methods are mainly described from the evaluation system, which indicators in the evaluation should consider and how to structure the evaluation system, it is seldom involved in the problem of multi-attribute decision-making. For example, [1] analyzed several mainstream energy evaluation index system, then proposed the Guizhou energy evaluation system on the basis of the actual situation in Guizhou. [2] evaluated several transport new energy through the energy consumption intensity and energy emission intensity. [3] and [4], respectively, proposed the energy evaluation method through the Analytic Hierarchy Process (AHP) and fuzzy comprehensive evaluation model for. [5] and [6] researched the relationship between energy and sustainable development, which also involved the construction of index system of energy evaluation. [7] using fuzzy AHP evaluation of energy were studied. These evaluation methods have two mainly problems: one is the evaluation methods are almost all qualitative evaluation, instead of quantitative analysis, the other is determining the indicators weights of quantitative analysis has a strong subjective which depends on the person’s subjective experience, these methods may have an influence on the rationality of the results.

As a mathematical tool to deal with uncertain, imprecise and inconsistent data, Rough Sets Theory [8, 9] rely on the data sheet to obtain the knowledge and rules, it’s a data-driven evaluation model, which can avoid the deviation irrationality of subjective decision-making. For example, Classic Pawlak rough sets have the advantage to deal with the classified data, in order to process the data with a partial order on some attributes, Greco, S[10, 11] proposed the Dominance Relation Rough Set model, of the relationship between rough set model. This theory provides a new approach to solve the ranking issue in the multi-attribute decision making[12], [13] applied this method to solve the sort problem of investment projects, [14] proposed a new ranking model based on dominance relation, but this model is proposed for the interval-valued information systems.

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2 Ranking model based on dominance relation

2.1 The basic concept of dominance relation

Definition 1 [15] Let $S = (U, A, V, f)$ be an Information system, where $U = \{x_1, x_2, ..., x_n\}$ is a non-empty finite set of objects, which is also called the domain, $A = \{a_1, a_2, ..., a_m\}$ is the a non-empty finite set of attributes, $V = \{V_a | a \in A\}$ is in the attributes value set of the object, $f: U \times A \rightarrow V$ is an information function, that is $f(x, a) \in V_a$. Specially, if all the attribute value sets $V_a$ has a preference order, that is the value domain is a totally ordered set, we call $S$ an ordered information system. The scope of this study will be limited to the ordered information system.

Definition 2 [12] Let $S = (U, A, V, f)$ be an Information system, for $B \subseteq A$, denote as

$$R_B = \{(x_i, x_j) | (x_i, x_j) \in U \times U \wedge \forall a \in A f(x_i, a) \geq f(x_j, a)\}$$

Then $R_B$ is called the dominance relation on $S$, $(x_i, x_j) \in R_B$ said object $x_i$ outbalance $x_j$ under the attribute set $B$, we can also write it as $x_i \geq_B x_j$.

Definition 3 [12] Let $S = (U, A, V, f)$ be an Information system, for $B \subseteq A, R_B$ is the dominance relation on $S$, denote as

$$[x_i]_B^\geq = \{x_j | (x_i, x_j) \in R_B\}$$

$[x_i]_B^\geq$ means the object set which outbalance $x_i$ under attribute set $B$, it is called the dominance class of $x_i$.

Similarly, we can define the inferior relation, the inferior class, the nature of dominance relation, inferior relation, dominance class and inferior class can refer to reference[12], we don’t repeat them here.

2.2 Ranking model in reference [12]

In order to take advantage of the dominance relation to get the order of the objects, reference [12] defines the dominance degree between two objects and the comprehensive dominance degree of an object as follows.

For dominance class $[x_i]_B^\geq$ and $[x_j]_B^\geq (x_i, x_j) \in U)$, using contain degree to compute the dominance degree of $x_i$ relative to $x_j$ under attribute set $B$, denote as

$$R_B(x_i, x_j) = \frac{|[x_i]_B^\geq \cup [x_j]_B^\geq|}{n}$$

where $n = |U|$, then we get the dominant matrix between each two objects, using the arithmetic mean to compute the comprehensive dominance degree of object $x_i$ under the attribute set $B$ as

$$R_B(x_i) = \frac{1}{n-1} \sum_{j \neq i} R_B(x_i, x_j)$$

The larger the value of $R_B(x_i)$, the more advantage object $x_i$ is, we can rank all objects from best to worst by the value of $R_B(x_i)$ in descending order.

Reference [12] said the dominance degree has two properties as follows.

1. $0 \leq R_B(x_i, x_j) \leq 1$
2. $x_i \geq_B x_j \Leftrightarrow [x_i]_B^\geq \subseteq [x_j]_B^\geq \Leftrightarrow R_B(x_i, x_j) = 1$.

But with scrutiny, it is not difficult to find the above definition has two defects. Firstly, in the relation of $R_B(x_i, x_j) \geq 0$, The equal sign can not be obtained, that is the inequality is a strictly inequality. By the reflexive of dominance relation, we known that for $\forall x_j \in U$, there is $[x_j]_B^\geq \neq \emptyset$, so $R_B(x_i, x_j) > 0$ is always correct. In fact, the general examples show that $R_B(x_i, x_j)$ generally gets value between $[0.5, 1.0]$, it is difficult to take the value between $[0.0, 0.5]$. The second and the much important issue is the element of dominance matrix does not satisfy “symmetry complementary” to each other, that is $R_B(x_i, x_j) + R_B(x_j, x_i) \neq 1 \forall i \neq j$. Therefore, the definition is of poor interpretability. For example, in properties (2), if there is $R_B(x_i, x_j) = 1$, then $R_B(x_j, x_i) = 0$ should be exist. Unfortunately, this dominance degree definition does not satisfy this feature, even when $R_B(x_i, x_j) = 1, R_B(x_j, x_i) = 1$ is also often a number close to 1.0, obviously, this definition does not truly reflect the dominance degree between any two objects.

To illustrate the irrationality of formula (1), using the data in table 1 to show it.

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A new improved ranking model

∀ Random dominance matrix defined in formula (3) has some natures as follows:

\[ x \in A \rightarrow \{x\} - \{x\} \]

where

\[ \{·\} - \{·\} \]

degree as follows

To improve the irrationality of dominance degree in formula (1), this paper proposes a new metric formula for dominance

Using formula (1), there is

Obviously, from table 1, we can see that

According to table 1, we can compute the dominance class as follows:

\[ [x_1]_A^3 = \{x_1, x_2, x_5, x_6\} \quad [x_2]_A^3 = \{x_2, x_5, x_6\} \quad [x_3]_A^5 = \{x_1, x_3, x_4, x_5, x_6\} \]

\[ [x_4]_A^2 = \{x_4, x_6\} \quad [x_5]_A^2 = \{x_5\} \quad [x_6]_A^2 = \{x_6\} \]

Using formula (1), there is

\[ R_A(x_1, x_2) = \frac{\sim [x_1]_A^3 \cup [x_2]_A^3}{n} = \frac{[\{x_3, x_4\} \cup \{x_2, x_5, x_6\}]}{n} = \frac{5}{6} \]

\[ R_A(x_2, x_1) = \frac{\sim [x_2]_A^3 \cup [x_1]_A^3}{n} = \frac{[\{x_1, x_3, x_4\} \cup \{x_1, x_2, x_5, x_6\}]}{n} = 1 \]

Obviously, from table 1, we can see that \( x_1 \) is not better than \( x_2 \) under all attributes of \( A \), however, from to dominance degree we get, the degree of \( x_1 \) outbalance \( x_2 \) is 5/6, which is approaching the degree of \( x_2 \) outbalance \( x_1 \), i.e. In addition, \( \forall i, j \), there is \( R_B(x_i, x_j) > 0 \), for the 36 elements of the dominance matrix, they all greater than or equal to 0.5 just except \( R_B(x_3, x_5) \) and \( R_B(x_3, x_6) \), so the definition of formula (1) is visible irrationality.

2.3 A new improved ranking model

To improve the irrationality of dominance degree in formula (1), this paper proposes a new metric formula for dominance degree as follows

\[ D_B(x_i, x_j) = \frac{|[x_i]_B^2 - [x_j]_B^2|}{(|[x_i]_B^2 - [x_i]_B^2|) \cup ([x_i]_B^2 - [x_j]_B^2)} \]  \quad (3)

where \( \{·\} - \{·\} \) means the difference of two sets, it composes the element which belongs to the former but not the latter set.

The definition can be interpreted as: \( [x_i]_B^2 \) and \( [x_j]_B^2 \) respectively means the objects that outbalance \( x_i \) and \( x_j \) in domain \( U \), so \( [x_i]_B^2 - [x_i]_B^2 \) is a set whose elements outbalance \( x_j \) but not \( x_i \), obviously, the more elements \( [x_j]_B^2 - [x_i]_B^2 \) has, the more \( x_j \) is exceeded, i.e. more objects outbalance \( x_j \) alone relative to \( x_i \), which means \( x_i \) is better than \( x_j \).

\( ([x_j]_B^2 - [x_i]_B^2) \cup ([x_i]_B^2 - [x_j]_B^2) \) is the sum of \( x_j \), better than \( x_i \) and \( x_j \), better than \( x_i \), because \( ([x_j]_B^2 - [x_i]_B^2) \cap ([x_i]_B^2 - [x_j]_B^2) = \emptyset \), then the ratio of the two expression is the dominance degree of \( x_i \) relative to \( x_j \).

After we get the dominant matrix between any two objects, using the arithmetic mean to compute the comprehensive dominance degree of object \( x_i \), under the attribute set \( B \) as

\[ D_B(x_i) = \frac{1}{n-1} \sum_{j=1}^{n} D_B(x_i, x_j) \]  \quad (4)

where \( n = |U| \), which is also the number of dominance class or the exponent number of the dominance matrix. The dominance matrix defined in formula (3) has some natures as follows:

(1) \( 0 \leq D_B(x_i, x_j) \leq 1 \);

(2) \( x_i \succeq_B x_j \Leftrightarrow [x_i]_B^2 \subseteq [x_j]_B^2 \Leftrightarrow D_B(x_i, x_j) = 1 \Leftrightarrow D_B(x_j, x_i) = 0 \);

(3) \( D_B(x_i, x_j) + D_B(x_j, x_i) = 1(i \neq j) \);

(4) \( D_B(x_i, x_i) = 0 \).

The natures above can be directly obtained from formula (3), the certification process is omitted here.
Nature (1) gives the domain of dominance degree, which is between 0 to 1, nature (2) gives the equivalent conditions when dominance degree can achieve the extremum, nature (3) shows that the dominance matrix satisfy "symmetry complementary", nature (4) shows that the elements on the diagonal are all 0, that is object \( x_i \) doesn’t outbalance itself.

From nature (1) (3) we know \( 0 \leq D_B(x_i, x_j) \leq 1 \) and \( D_B(x_i, x_j) + D_B(x_j, x_i) = 1 (i \neq j) \), so dominance degree can also be understand as the probability of dominance between two objects if \( D_B(x_i, x_j) = 1 \), then \( x_i \) is absolutely superior to \( x_j \), if \( D_B(x_i, x_j) = 0 \), then \( x_i \) is absolutely not superior to \( x_j \), others, \( D_B(x_i, x_j) \) means \( x_i \) is superior to \( x_j \) with the probability of \( D_B(x_i, x_j) \). This interpretation is more realistic than formula (1), it has a better semantic.

In addition, formula (4) also makes a slight improvement compared to formula (2), because of \( D_B(x_i, x_i) = 0 \), so when we calculate the comprehensive dominance degree, whether to exclude the diagonal elements does not affect the final results, but formula (4) is more to facilitate the entire column or row operation of the matrix, when we are faced with a large scale of data, the implementation efficiency on the computer may have some differences.

It is noteworthy that, nature (4) shows that object \( x_i \) to its own dominance degree is 0, so when two or more objects are exactly the same under all attributes, there will be \( [x_i]_B^2 = [x_j]_B^2 \), that is \( D_B(x_i, x_j) = D_B(x_j, x_i) = 0 \), the dominance matrix calculated will not satisfy nature (3). Although this feature will not affect the sorting results, when elements of dominance matrix do not meet the nature (3), the nature of the matrix is poor, it’s not conducive to more in-depth study and exploration. So, before we structure the dominance matrix, we merge the dominance class who satisfy \( [x_i]_B^2 = [x_j]_B^2 \), then do it on the amended dominance class, and let \( x_j \) have no difference with \( x_i \) while ranking the objects, recorded as \( x_i \sim x_j \). Here \( n \) is no longer \( |U| \), but the remainder of the dominance class number after merged operation, or the exponent number of the dominance matrix.

We still use data in table 1 as example, according to the dominance class above, structure the dominance matrix by formula (3), the results as follows:

\[
D = \begin{bmatrix}
0 & 0 & 2/3 & 1/4 & 0 & 0 \\
1 & 0 & 1 & 1/3 & 0 & 0 \\
1/3 & 0 & 0 & 0 & 0 & 0 \\
3/4 & 2/3 & 1 & 0 & 1/3 & 0 \\
1 & 1 & 1 & 2/3 & 0 & 1/2 \\
1 & 1 & 1 & 1 & 1/2 & 0
\end{bmatrix}
\]

Then calculate the comprehensive dominance degree by formula (4), i.e. \( D_B(x_1) = 11/60, D_B(x_2) = 28/60, D_B(x_3) = 4/60, D_B(x_4) = 33/60, D_B(x_5) = 50/60, D_B(x_6) = 54/60 \). Now, we can rank the objects from best to worst, that is \( x_6 \succ x_5 \succ x_4 \succ x_2 \succ x_1 \succ x_3 \) (\( \succ \) means "better than").

The sort results are basic consistent with our intuitive feel got from the data table 1, and the generally weighted average method is difficult to get this result, this ranking method completely avoid to determine the weight by human subjective experience, it’s more objective and scientific.

### 3 An application instance of energy evaluation

#### 3.1 Indicators choosing

We live in the era of the energy shortage, but had to pursue the rapid development and sustainable development at the same time. Using comprehensive evaluation to determine the advantages and disadvantages of energy, to provide the basis for the use and exploitation of energy, to provide direction to find new energy, has very important significance.

Determining the energy evaluation subjects(i.e. the set of objects), we consider several frequent used energy and the new energy which is gradually entering the society. Here, we consider eight kinds of energy as follows: coal, oil, natural gas, wind, hydro, nuclear, solar, bio- energy, so remember them as \( x_1, x_2, ..., x_8 \), i.e. \( U = \{x_1, x_2, ..., x_8\} \).

When we determine the indicators of the energy evaluation, we must not only consider the economic benefits of energy, but also consider the impact of energy on society and the environment, and energy technical conditions for development is also important. Society advocate sustainable development, so the impact on society and environment takes more concern and attention. Therefore, this article evaluate the energy from four aspects, that is, economic benefits, environmental benefits, technical benefits and social benefits, remember them as \( C_1, C_2, C_3, C_4 \). In order to have a more accurate evaluation, further subdivided the four indicators into 12 two indicators, they are \( C_1 \) (Project internal rate of return, The output energy of unit cost), \( C_2 \) (Impact on the surrounding water environment, Impact on the surrounding atmospheric environment, Impact on the surrounding soil environment, Impact on the surrounding social environment), \( C_3 \) (Technology maturity, Development prospects and potential of the technology), \( C_4 \) (Energy renewability, Providing job opportunities, Acceptable levels to the masses). Remember them as \( a_1, a_2, ..., a_{12} \), that is \( A = \{a_1, a_2, ..., a_{12}\} \). In all indicators, they...
It can be seen from table 3 that if directly to find the dominance class under all the 12 attributes, there will be many objects difficult to compare except environmental benefits, the direct effect of energy on the environment is general cost indicators, namely, the friendliness level to surrounding water environment, the friendliness level to surrounding atmosphere environment, the friendliness level to surrounding soil environment, the friendliness level to surrounding social environment.

3.2 Data collection and pretreatment

After we determine the evaluation object and evaluation indicators, it is necessary to determine the value of each object in the indicators, for simplicity, use the data given in reference [3], the raw data is shown in table 2.

In order to properly eliminate the impact of data errors, we will make the continuous value information table discretization. Assume the value of the attributes in the information table is the score got by each object under each attribute, take the maximum difference discretization method to discretize each attribute. To simplify the problem, the values of each attribute is discretized into three levels, it can be interpreted as excellent, well and general three types, corresponding to a discrete attribute values 3, 2, 1.

3.3 Comprehensive evaluation of energy

It can be seen from table 3 that if directly to find the dominance class under all the 12 attributes, there will be many objects difficult to compare except $x_1$, $x_2$, $x_3$ and $x_7$, $x_8$ internal. The sort results obtained by this method is not ideal, there are more objects difficult to distinguish, it is difficult to reflect the pros and cons of relationships between objects. So we consider a hierarchical ranking model. That is, firstly we divide the ordered information table into four table by the first level indicator $C_1$, $C_2$, $C_3$, $C_4$, then we calculate the dominance class respectively, get the ranking results under...
C_1, C_2, C_3, C_4, then consider the new information table whose object value is the ranking result value in first step, using the same method to rank the objects to obtain the final sort result.

Under C_1, C_2, C_3, C_4, we can calculate the dominance class of 8 objects as follows:

$$\begin{align*}
[x_1]_{C_1}^2 & = \{x_1, x_2, x_3, x_6\} & [x_1]_{C_2}^3 & = \{x_1, x_2, ..., x_8\} & [x_1]_{C_3}^4 & = \{x_1, x_2, x_3, x_7, x_8\} \\
[x_2]_{C_1}^2 & = \{x_2, x_3\} & [x_2]_{C_2}^3 & = \{x_1, x_2, ..., x_8\} & [x_2]_{C_3}^4 & = \{x_2, x_3\} \\
[x_3]_{C_1}^2 & = \{x_2, x_3\} & [x_3]_{C_2}^3 & = \{x_2, x_3, ..., x_7\} & [x_3]_{C_3}^4 & = \{x_1, x_2, x_7, x_8\} \\
[x_4]_{C_1}^2 & = \{x_4, x_7, x_8\} & [x_4]_{C_2}^3 & = \{x_4\} & [x_4]_{C_3}^4 & = \{x_4, x_7\} \\
[x_5]_{C_1}^2 & = \{x_4, x_5, x_7, x_8\} & [x_5]_{C_2}^3 & = \{x_4, x_5, x_7, x_8\} & [x_5]_{C_3}^4 & = \{x_4, x_7\} \\
[x_6]_{C_1}^2 & = \{x_1, x_2, x_3, x_6\} & [x_6]_{C_2}^3 & = \{x_6, x_7, x_8\} & [x_6]_{C_3}^4 & = \{x_5, x_7, x_8\} \\
[x_7]_{C_1}^2 & = \{x_4, x_7, x_8\} & [x_7]_{C_2}^3 & = \{x_7\} & [x_7]_{C_3}^4 & = \{x_7\} \\
[x_8]_{C_1}^2 & = \{x_1, x_2, x_3, x_7, x_8\} & [x_8]_{C_2}^3 & = \{x_7, x_8\} & [x_8]_{C_3}^4 & = \{x_7, x_8\}
\end{align*}$$

Under C_1, there is \(x_1 ~ x_6, x_2 ~ x_3, x_4 ~ x_7 ~ x_9\) (means the objects having no difference), merger them and denote as \([x_1']_{C_1}^2\), \([x_2']_{C_1}^2\), \([x_4']_{C_1}^2\), \([x_6']_{C_1}^2\), then \(n_1 = 4\). Similarly, under C_2, there is \(x_1 ~ x_2 ~ x_3 ~ x_6\), merger it and denote as \([x_1']_{C_2}^3\), \(n_2 = 5\); under C_3, there is \(x_2 ~ x_3\), merger it and denote as \([x_2']_{C_3}^4\), \(n_3 = 7\); under C_4, there is \(x_1 ~ x_2 ~ x_3\), merger it and denote as \([x_1']_{C_4}^4\), \(n_4 = 6\).

After merger the objects, calculate the dominance matrix according to formula (3), denoted as \(D_1, D_2, D_3, D_4\), then

\[
D_1 = \begin{bmatrix}
1/3 & 0 & 3/7 & 1/2 \\
1 & 0 & 3/5 & 2/3 \\
4/7 & 2/5 & 0 & 1 \\
1/2 & 1/3 & 0 & 0
\end{bmatrix}
\]

\[
D_2 = \begin{bmatrix}
0 & 0 & 0 & 0 \\
1 & 0 & 1 & 1/2 \\
1 & 0 & 0 & 1/2 \\
1 & 0 & 1/2 & 0
\end{bmatrix}
\]

\[
D_3 = \begin{bmatrix}
0 & 0 & 2/3 & 4/5 & 2/5 & 1/4 & 2/5 \\
1 & 0 & 1/2 & 1 & 1/2 & 1/3 & 1/2 \\
1/3 & 1/2 & 0 & 1/2 & 0/2 & 0 & 1/2 \\
1/5 & 0 & 0 & 0 & 0 & 0 & 1/6 \\
3/5 & 1/2 & 1/2 & 0 & 0 & 1/2 & 0 \\
3/4 & 2/3 & 1 & 1 & 1 & 0 & 1 \\
3/5 & 1/2 & 5/6 & 1/2 & 0 & 0
\end{bmatrix}
\]

\[
D_4 = \begin{bmatrix}
0 & 0 & 0 & 0 & 1/5 & 1/4 & 1 & 0 \\
4/5 & 1 & 2/3 & 0 & 1 & 3 & 1/2 \\
4/5 & 1/3 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 1 \\
1 & 1 & 1 & 1 & 0 & 0 & 0 \\
1 & 1/2 & 1 & 1 & 0 & 0 & 0
\end{bmatrix}
\]

Compute the comprehensive dominance degree according to formula (4), that is

\[
D_1(x_1) = \frac{1}{3} \times (0 + 0 + \frac{3}{7} + \frac{1}{2}) = \frac{13}{42} \approx 0.31
\]

Similarly, we can get the comprehensive dominance degree of each objects respectively under \(D_1, D_2, D_3, D_4\), show them as a vector, that is:

\[
D_1(x_1) = (0.31, 0.76, 0.66, 0.28) \\
D_2(x_1) = (0, 0.7, 0.3, 0.3, 0.7) \\
D_3(x_1) = (0.30, 0.48, 0.33, 0.03, 0.37, 0.63, 0.42) \\
D_4(x_1) = (0.29, 0.42, 0.30, 0.71, 0.50)
\]

So we obtain the ranking result of each object under the four first-level indicators, that is:

\[
C_1: x_2 ~ x_3 ~ x_4 ~ x_7 ~ x_8 ~ x_1 ~ x_6 ~ x_5 \\
C_2: x_4 ~ x_7 ~ x_5 ~ x_6 ~ x_1 ~ x_2 ~ x_3 ~ x_8 \\
C_3: x_7 ~ x_3 ~ x_5 ~ x_6 ~ x_8 ~ x_4 ~ x_1 ~ x_5 \\
C_4: x_7 ~ x_5 ~ x_4 ~ x_5 ~ x_1 ~ x_2 ~ x_3 ~ x_6
\]

In order to get the final sorting results, assign each object a integer value from 1 to 8 under each first-level indicator by the ranking result above, the more excellent a object, the larger its value gets, the same good object are given the same score, we obtain the data shown in table 4.

According to the information table above, calculate the objects’ dominance class under the attributes \(C = \{C_1, C_2, C_3, C_4\}\), the result are: \([x_1]_{C_1}^2 = \{x_1, x_2, x_3, x_4, x_7, x_8\}, [x_1]_{C_2}^3 = \{x_2, x_3\}, [x_1]_{C_3}^4 = \{x_2, x_3\}, [x_1]_{C_4}^4 = \{x_2, x_7\}, [x_2]_{C_1}^3 = \{x_4, x_5, x_7\}, [x_2]_{C_3}^4 = \{x_7, x_8\}, [x_3]_{C_1}^3 = \{x_4, x_7\} \), there is also \(x_2]_{C_3}^4 = \{x_3]_{C_4}^4 = \{x_8]_{C_4}^4 = \{x_7, x_8\}\), merge them and
Table 4: the sort the results under four first-level indicators

<table>
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<tr>
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<th>A2</th>
<th>A3</th>
<th>A4</th>
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<td>1</td>
</tr>
<tr>
<td>x7</td>
<td>4</td>
<td>7</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>x8</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 5: sort results comparison between this paper and reference [3]

<table>
<thead>
<tr>
<th>energy</th>
<th>coal</th>
<th>oil</th>
<th>natural</th>
<th>gas</th>
<th>wind</th>
<th>hydro</th>
<th>nuclear</th>
<th>solar</th>
<th>bio-energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>The result of this paper</td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>7</td>
<td>6</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>The result of reference [3]</td>
<td>8</td>
<td>6</td>
<td>7</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

donate as $|x'_2| ^{2} C$, then $n = 7$, get the dominance matrix as

$$D = \begin{bmatrix}
0 & 0 & 0 & 1/5 & 1/6 & 0 & 0 \\
1 & 0 & 1/2 & 3/5 & 1/2 & 1/3 & 1/2 \\
1 & 1/2 & 0 & 1 & 1/2 & 0 & 1/2 \\
4/5 & 2/5 & 0 & 0 & 1/3 & 0 & 1/3 \\
5/6 & 1/2 & 1/2 & 2/3 & 0 & 0 & 1/2 \\
1 & 2/3 & 1 & 1 & 1 & 0 & 1 \\
1 & 1/2 & 1/2 & 2/3 & 1/2 & 0 & 0
\end{bmatrix}$$

Compute the comprehensive dominance degree, that is

$$D(x_i) = (0.06, 0.57, 0.58, 0.31, 0.50, 0.94, 0.53)$$

Now we can rank all the 8 objects from best to worst as the final sort result

$$x_7 \succ x_4 \succ x_2 \sim x_3 \succ x_8 \succ x_6 \succ x_5 \succ x_1$$

The result shows that $x_7$ (solar energy) is the best energy relatively, $x_1$ (coal) is the worst energy. The sort results comparison between this paper and reference [3] are shown in table 5.

### 3.4 Result analysis

Result can be seen from table 5, for the two ranking method, the top two objects and the last object are consistent. That is, the solar and wind energy is the better energy, and coal become the worst energy. This result exemplifies the environmental protection and renewable sources advantage of the solar and wind energy. While coal resources is widely used, because of its pollution and non-renewability and so on, it only gets the worst evaluation among the 8 kind of energy. The result is consistent with the energy goals of present advocated clean energy and sustainable development.

Furthermore, the fifth and sixth energy of this article sort are basically consistent with the result listed in reference [3], they are relatively backward one order because the oil and gas sort have a large raise. This paper argues that the oil and gas has a greater influence on the environment, but the influence is not so serious compared to coal resources relatively. Because these two energy has major advantages of technology maturity and providing job opportunities, making it still occupies a very important role in the moment several energy. We should make full use of its advantages, while guard against its environmental impact, then they are still a good energy choices.

In addition, this paper presents a same sort result of the oil and natural gas, observe the data in table 2, both score of the two objects under 12 indicators are basic about the same, it is hard to compare which is better, after data discretization, they get the same level of classification (in table 3), so we think the two objects ranked side by side is reasonable (in reference [3], their finally comprehensive score only has a difference of 0.0033, which is very close).
Finally, this paper ranks the hydro energy as the second worst energy, which has a big gap compared to the original sort of the third, in fact, we can also see it from table 2, the values has no special advantages under any indicators. Therefore, in the comparison of energy, it will inevitably have disadvantage compared to the other energy who has advantages under some indicators. Although the water is for our well-known energy and commonly used, it is difficult to obtain further explore space, so it only exist as a maintain necessities of our production and living.

Throughout the previous analysis, we think the sort result given by the ranking model based on dominance relations is consistent with the current energy development goals and trends, reflects the actual situation of energy, it’s more reasonable compared to reference [3] which is obtained by using of subjective weights to sort the objects.

4 Conclusion

In this paper, we take advantage of the unique advantages of dominance relation based on rough set theory to process data, research the ranking model based on dominance relation, analyze the defects and deficiencies of dominance degree measure definition in current ranking models, use an example to demonstrate the rationality and effectiveness of the new sort method. Finally, we use the ranking model to evaluate eight kind of energies and discuss it in details, we obtain a more satisfactory result by a hierarchical ranking model, through comparative analysis of the result in this paper and original sorting method, the result shows that ours are more reasonable.

Due to space limitation and discussion focus, we just give the related properties a simple statement of dominance relations ranking model, not containing any proof, the deeper nature of dominance degree and dominance matrix is not contained in this paper. In addition, apply and promote this approach to other areas, this article does not analysis, these will be the follow-up work and further efforts direction.

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References


LINS homepage: http://www.nonlinearscience.org.uk/
