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Research Article

Crop Evaluation System Optimization: Attribute Weights Determination Based on Rough Sets Theory

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The present study is mainly a continuation of our previous study, which is about a crop evaluation system development that is based on grey relational analysis. In that system, the attribute weight determination affects the evaluation result directly. Attribute weight is usually ascertained by decision-makers experience knowledge. In this paper, we utilize rough sets theory to calculate attribute significance and then combine it with weight given by decision-maker. This method is a comprehensive consideration of subjective experience knowledge and objective situation; thus it can acquire much more ideal results. Finally, based on this method, we improve the system based on ASP.NET technology.

1. Introduction

Since Ju-Long proposed grey relational system in 1982 [1, 2], scholars have employed this theory making a lot of research works [3–6]. In the agricultural industry, Ma et al. utilize it to evaluate new self-cultivated sugarcane lines, Yan and Shen evaluate carding cashmere fiber and Zhang et al. evaluate new watermelon varieties [7–9]. Based on these previous works, we have developed a crop evaluation system based on grey relational analysis (GRA) [10]. The experiment results showed that the crop evaluation system is effective and could greatly improve the work efficiency of the researcher and expand the application scope. When we exploit GRA method to evaluate crops, attribute weight ascertainment plays an important role, because it affects the evaluation result directly.

In the management of multiple attribute decision-making system, people often take multiple indexes as evaluation standard for alternative scheme filtration. In the process of evaluation and decision-making, attribute weight is essential. It reflects the status or role of various factors and directly affects the final judgment and decision-making. We usually ascertain attribute weight based on the importance of each attribute. There are lots of classic decision methods, that is, AHP, TOPSIS, ELECTRE, and so forth [11, 12]. Although those methods promote the development of decision theory, the attribute weight is generally given by experts [10]. Potential uncertainty in expert judgment is the main disadvantage of the subjective methods. The weight determination is much affected by expert experience knowledge and sometimes is not able to objectively reflect the actual situation and even can distort the judgment and decision result [13].

In 1982, professor Pawlak proposed a theory of rough sets [14], which provides a formal tool for dealing with imprecise or incomplete information. Since its introduction, the theory has generated a great deal of interest along researchers [15–17], as well as among researchers dealing with machine learning and knowledge acquisition for expert systems [18–22]. It is used for knowledge acquisition and analysis without providing any a priori information and fully reflects the objectivity of data.

This paper presents a new method to determine attribute weights based on the theory of rough sets. First, objective weight value is derived by significance in the theory of rough sets [23–27]. And then, according to practical application background, we combine objective weight with subjective weight determined by expert experience knowledge and ascertain the final weight value so as to realize reasonable unification of subjective prior knowledge and objective situation. Finally, we utilize ASP.NET programming language to improve the crop evaluation system.

In this paper, first, in Section 2, we present preliminary and notation of the theory of rough sets. Section 3 is the algorithm of attribute weight determination. Section 4 is the real example in Fuji apple evaluation. In Section 5, we utilize ASP.NET to improve the system.

2. Methods

2.1. Theory of Rough Sets. The notion of equivalence is introduced first. R is the equivalence relation defined on U, where U is the universe of objects. A binary relation $R \subseteq X \times Y$ which is reflexive (i.e., an object is in relation with itself, xRx), symmetric (if xRy, then yRx), and transitive (if xRy and yRz, then xRz) is called an equivalence relation [28]. $X \subset U$ is a subset of U. $[x]_R$ is the equivalence class generated by equivalence relation R. The equivalence class of an element $x \in X$ consists of all objects $y \in X$ such that xRy. Let $A = (U, A)$ be an information system and let $R \subseteq A$ and $X \subseteq U$. We can approximate X using only the information contained in R by constructing the R-lower and R-upper approximations of X, denoted as $R\_(X)$ and $R^{-}(X)$, respectively, where $R\_(X) = \{x \in U \mid [x]_R \subset X\}$ and $R^{-}(X) = \{x \in U \mid [x]_R \cap X \neq \phi\}$. The objects in $R\_(X)$ can be with certainty classified as members of X on the basis of knowledge in R, where the objects in $R^{-}(X)$ can be only classified as possible members of X on the basis of knowledge in R. If $R\_(X) \neq R^{-}(X)$, set X is said to be rough.

2.2. Information System. Let $S = (U, A, V, f)$ be an information system such that U denotes a nonempty finite set of objects, called universe. $A = C \cup D$ is attribute set; subsets C and D are called condition attribute set and decision attribute set, respectively. $V = \bigcup_{a\in A} V_a$ are the sets of attribute value. $f : U \times A \rightarrow V$ is information function, which specifies the attribute value of object x of set U. With any subsets $B \subseteq A$, there is an associated equivalence relation $\mathrm{IND}_A(B)$:

$$\mathrm{IND}_A(B) = \left\{(x, y) \mid (x, y) \in U^2,\ \forall a \in B, f(x, a) = f(y, a)\right\}. \tag{1}$$

$\mathrm{IND}_A(B)$ is called B-indiscernibility relation and the subscript A is usually omitted if it is clear which information system is meant. $\mathrm{IND}(B) = \bigcap_{b\in B} \mathrm{IND}(\{b\})$ is obvious. The equivalence relation $\mathrm{IND}(B)$ constitutes the partition of U, denoted by $U/\mathrm{IND}(B)$ and often abbreviated to U/B.

2.3. Attribute Significance. In this section, we will introduce basic definition of attribute significance [29–31]. We utilize the attribute reduction method of the theory of rough sets to ascertain each attribute's significance. Using attribute reduction, we find core attribute and reduce unnecessary attribute and determine the important relation between attributes. On the other hand, after reducing one attribute, we define attribute contribution degree through judging the variation size of system structure. The bigger the variation size is, the greater the attribute weight is.

In an information system, we define $\mathrm{Sig}_B(a)$ as attribute a significant for subset B:

$$\mathrm{Sig}_B(a) = 1 - \frac{|B \cup \{a\}|}{|B|}, \tag{2}$$

where $|B| = |\mathrm{IND}(B)|$; set $U/\mathrm{IND}(B) = U/B = \{X_1, X_2, \ldots, X_n\}$; then $|B| = \sum_{i=1}^{n} \sum |X_i|^2$.

In practice, when we apply formula (2) to calculate the contribution degree, we may encounter this situation: some attribute contribution degrees are 0 or have same values, which do not accord with facts. In order to solve this problem, we define the improvement significance formula.

$$\mathrm{Sig}'_{B_i} = \left|\mathrm{Sig}_{B_i}(b_i) - \frac{1}{n-1}\sum_{j=1(j\neq i)}^{n}\left[\frac{\mathrm{Sig}_{B_{i,j}}(b_i, b_j) - \mathrm{Sig}_{B_i}(b_i)}{2}\right]\right|, \tag{3}$$

where $B \subseteq C$ is subset of attribute set C, $B = \{b_1, b_2, \ldots, b_n\}$, b_i is an attribute, $B_i = B - \{b_i\}$, and $B_{i,j} = B - \{b_i, b_j\}$.

3. Attribute Weight Ascertainment

We carry out the normalization processing of attribute significance to obtain the objective weight (OW) of each attribute. The calculation formulas, respectively, corresponding to formulas (2) and (3) are as follows:

$$\mathrm{OW}(a_i) = \frac{\mathrm{Sig}_B(a_i)}{\sum_{i=1}^{n} \mathrm{Sig}_B(a_i)}, \tag{4}$$

$$\mathrm{OW}'(a_i) = \frac{\mathrm{Sig}'_B(a_i)}{\sum_{i=1}^{n} \mathrm{Sig}'_B(a_i)}. \tag{5}$$

Then combine the subjective weight (SW) and OW to get the final weight (FW) formula as follows:

$$\mathrm{FW}(a_i) = (1 - \lambda)\,\mathrm{OW}(a_i) + \lambda \mathrm{SW}(a_i), \tag{6}$$

where $\lambda \in (0, 1)$ is constant.

4. The Analysis of Influence Factors in Fuji Apple

In order to verify the effectiveness of weight acquisition method, we still adopt the previous paper's data for comprehensive evaluation: Fuji apple evaluation data [7] are shown in Table 1. Before analysis, we need to discrete the data according to the following method. First, calculate each attribute value interval as approximate distribution interval; then, set ideal variety data as objective value and suppose it has 5% fluctuation in random distribution interval; finally, judge whether each attribute value falls into ideal value interval and then assign discrete value of 1 or 0, respectively,

Table 1: Experimental data.

Input the crop name: Apple				Input characters number: 8				
Input the weight	0.08	0.16	0.16	0.16	0.04	0.16	0.16	0.08
Characters names	Fruit volume	Skin color	Flesh color	Starch content	The juice yield	Solid acid ratio	Fruit firmness	Protein content
Ideal variety	320.00	12.00	−0.20	0.40	58.00	55.00	273.71	0.56
1	318.22	13.40	0.35	0.47	57.52	48.11	273.71	0.30
2	227.22	14.10	0.09	0.65	73.47	64.71	252.86	0.46
3	240.33	11.10	0.17	0.59	64.13	76.05	273.05	0.37
4	319.33	17.23	0.06	0.66	68.46	48.39	248.93	0.27
5	224.67	13.37	0.13	0.74	62.49	52.31	275.93	0.31
6	275.67	9.89	−0.20	0.99	67.22	55.26	247.04	0.38
7	289.44	12.97	0.29	0.48	59.93	42.96	247.04	0.45
8	305.56	10.87	0.25	0.99	67.25	49.17	226.14	0.35
9	288.22	16.45	0.11	0.43	62.55	38.33	269.13	0.56

Table 2: Decision table.

U	C							
	a	b	c	d	e	f	g	h
1	1	0	0	0	1	0	1	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	1	0
4	1	0	0	0	0	0	0	0
5	0	0	0	0	0	0	1	0
6	0	0	1	0	0	1	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	1	0	0	0	1

and establish the decision table $T = \langle U, C\rangle$, as shown in Table 2, where $U = \{1,2,3,4,5,6,7,8,9\}$ and $C = \{a,b,c,d,e,f,g,h\}$ corresponding to eight attributes.

Employing the method introduced in Section 2.3, we calculate attribute significance. Set $C_1 = \{b,c,d,e,f,g,h\}$, $\ldots, C_8 = \{a,b,c,d,e,f,g\}$.

According to equivalence relation, we gain

$$\begin{aligned}
\text{IND}(C) &= \{\{1\},\{2,7,8\},\{3,5\},\{4\},\{6\},\{9\}\};\\
\text{IND}(C_1) &= \{\{1\},\{2,4,7,8\},\{3,5\},\{6\},\{9\}\};\\
\text{IND}(C_2) &= \{\{1\},\{2,7,8\},\{3,5\},\{4\},\{6\},\{9\}\};\\
\text{IND}(C_3) &= \{\{1\},\{2,7,8\},\{3,5\},\{4\},\{6\},\{9\}\};\\
\text{IND}(C_4) &= \{\{1\},\{2,7,8\},\{3,5\},\{4\},\{6\},\{9\}\};\\
\text{IND}(C_5) &= \{\{1\},\{2,7,8\},\{3,5\},\{4\},\{6\},\{9\}\};\\
\text{IND}(C_6) &= \{\{1\},\{2,7,8\},\{3,5\},\{4\},\{6\},\{9\}\};\\
\text{IND}(C_7) &= \{\{1\},\{2,3,5,7,8\},\{4\},\{6\},\{9\}\};\\
\text{IND}(C_8) &= \{\{1\},\{2,7,8\},\{3,5\},\{4\},\{6\},\{9\}\}.
\end{aligned} \tag{7}$$

According to formula (2), we calculate attribute significance:

$$\begin{aligned}
&\text{Sig}_{C_1}(a) = \frac{6}{23},\\
&\text{Sig}_{C_2}(b) = \text{Sig}_{C_3}(c) = \text{Sig}_{C_4}(d) = \text{Sig}_{C_5}(e)\\
&\qquad = \text{Sig}_{C_6}(f) = \text{Sig}_{C_8}(h) = 0,\\
&\text{Sig}_{C_7}(g) = \frac{12}{29}.
\end{aligned} \tag{8}$$

Obviously, this result jibes with objective cognition. When we consume apples, we maybe focus on the intuitive attributes "a" and g to evaluate them. But significance of attributes "b," "c," "d," "e," "f," and "h" is 0; the result is not scientific, so we employ formula (3) to calculate significance. Let

$$\begin{aligned}
&C_{(a,b)} = \{c,d,e,f,g,h\},\ldots, C_{(a,h)} = \{b,c,d,e,f,g\},\\
&\frac{U}{C_{(a,b)}} = \{\{1\},\{2,4,7,8\},\{3,5\},\{6\},\{9\}\},\\
&\frac{U}{C_{(a,c)}} = \{\{1\},\{2,4,7,8\},\{3,5\},\{6\},\{9\}\},\\
&\frac{U}{C_{(a,d)}} = \{\{1\},\{2,4,7,8\},\{3,5\},\{6\},\{9\}\},\\
&\frac{U}{C_{(a,e)}} = \{\{1,3,5\},\{2,4,7,8\},\{6\},\{9\}\},\\
&\frac{U}{C_{(a,f)}} = \{\{1\},\{2,4,7,8\},\{3,5\},\{6\},\{9\}\},\\
&\frac{U}{C_{(a,g)}} = \{\{1\},\{2,3,4,5,7,8\},\{6\},\{9\}\},\\
&\frac{U}{C_{(a,h)}} = \{\{1\},\{2,4,7,8\},\{3,5\},\{6\},\{9\}\}.
\end{aligned} \tag{9}$$

According to formula (2), we can acquire the following result:

$$\begin{aligned}
&\text{Sig}_{C_{(a,b)}}(a,b) = \frac{6}{23},\\
&\text{Sig}_{C_{(a,c)}}(a,c) = \frac{6}{23},\\
&\text{Sig}_{C_{(a,d)}}(a,d) = \frac{6}{23},\\
&\text{Sig}_{C_{(a,e)}}(a,e) = \frac{10}{27},\\
&\text{Sig}_{C_{(a,f)}}(a,f) = \frac{6}{23},
\end{aligned}$$

$$\mathrm{Sig}_{C_{(a,g)}}(a,g)=\frac{22}{39},$$
$$\mathrm{Sig}_{C_{(a,h)}}(a,h)=\frac{6}{23}. \quad (10)$$

Then we plug the above result into formula (3); we calculate the improvement significance of attribute a:

$$\mathrm{Sig}'_{C_1}(a)=\left|\mathrm{Sig}_{C_1}(a)-\frac{1}{7}\sum_{i=b}^{h}\left(\frac{\mathrm{Sig}_{C_{(a,i)}}(a,i)-\mathrm{Sig}_{C_1}(a)}{2}\right)\right|=0.2314. \quad (11)$$

By the same procedure, we gain another attribute significance:

$$\begin{aligned}\mathrm{Sig}'_{C_2}(b)&=0.0482,\\ \mathrm{Sig}'_{C_3}(c)&=0.0668,\\ \mathrm{Sig}'_{C_4}(d)&=0.0668,\\ \mathrm{Sig}'_{C_5}(e)&=0.0587,\\ \mathrm{Sig}'_{C_6}(f)&=0.0668,\\ \mathrm{Sig}'_{C_7}(g)&=0.4004,\\ \mathrm{Sig}'_{C_8}(h)&=0.0668.\end{aligned} \quad (12)$$

According to formula (5), we normalize the above value to get each attribute's OW:

$$\begin{aligned}\mathrm{OW}(a)&=0.2300,\\ \mathrm{OW}(b)&=0.0480,\\ \mathrm{OW}(c)&=0.0664,\\ \mathrm{OW}(d)&=0.0664,\\ \mathrm{OW}(e)&=0.0584,\\ \mathrm{OW}(f)&=0.0664,\\ \mathrm{OW}(g)&=0.3980,\\ \mathrm{OW}(h)&=0.0664.\end{aligned} \quad (13)$$

Then, combine the SW and OW to get the FW; suppose $\lambda=0.8$:

$$\begin{aligned}\mathrm{FW}(a)&=0.11,\\ \mathrm{FW}(b)&=0.14,\\ \mathrm{FW}(c)&=0.14,\\ \mathrm{FW}(d)&=0.14,\\ \mathrm{FW}(e)&=0.04,\\ \mathrm{FW}(f)&=0.14,\\ \mathrm{FW}(g)&=0.21,\\ \mathrm{FW}(h)&=0.08.\end{aligned} \quad (14)$$

In the calculation of the subjective weight, we not only consider the internal relations of factors but also avoid situations where the attribute weight is 0. Therefore, it is a good method to determine the weight of single attribute by means of the importance of single attribute and the importance of combination attributes.

In the previous paper, attribute weight is ascertained by decision-makers experience knowledge. Since individual architectonic knowledge is different, results vary with each individual. Compared with the previous paper, the result by the proposed method is more reasonable [29].

Rescale the parameter value to obtain different FW.

5. Crop Evaluation System Optimization

We utilize C# programming language to improve the system and add two input boxes: floating rate and value of λ. The former determines OW; the latter determines proportion of OW and SW in FW. Set $\lambda=1$; FW equals SW; the curve is the same as previous paper, shown in Figure 1. Set $\lambda=0.8$ to get different curve. The result is in accord with conclusion produced in Section 4, shown in Figure 2.

6. Conclusion

Utilizing attribute significance concept, the present paper introduces a new weight ascertainment method. It overcomes former method deficiency that attribute weight determination relies too much on expert experience knowledge. Since individual architectonic knowledge is different, results vary with each individual. By adding objective attribute weight, decisions makers can combine own interests and specific application to choose the appropriate performance coefficient adjustment of subjective weight and objective weight ratio, making the evaluation result more reasonable. Finally, we utilize C# programming language to improve the system, which is more convenient for agricultural researchers to employ.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

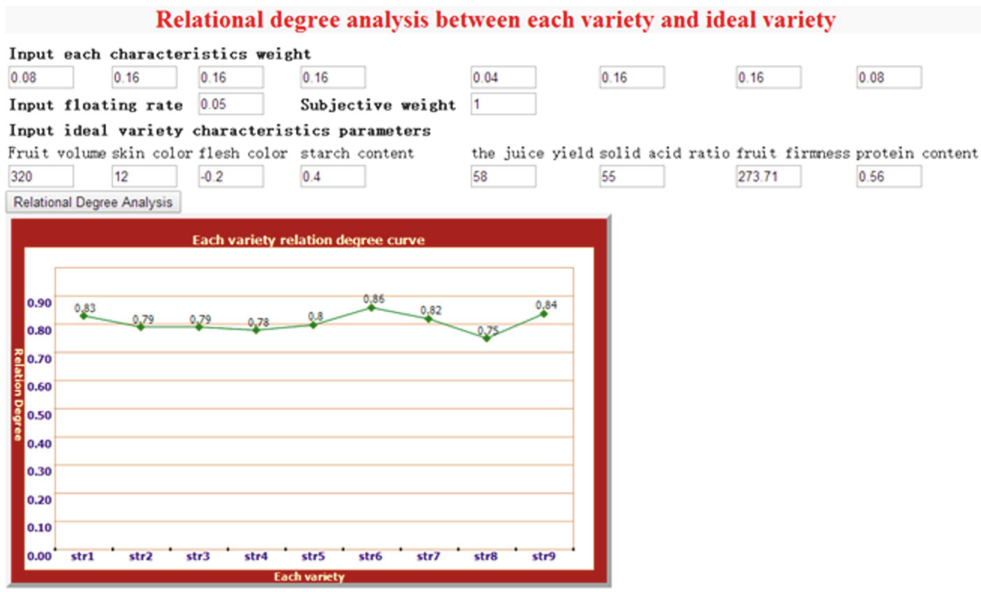

Figure 1: Original curve.

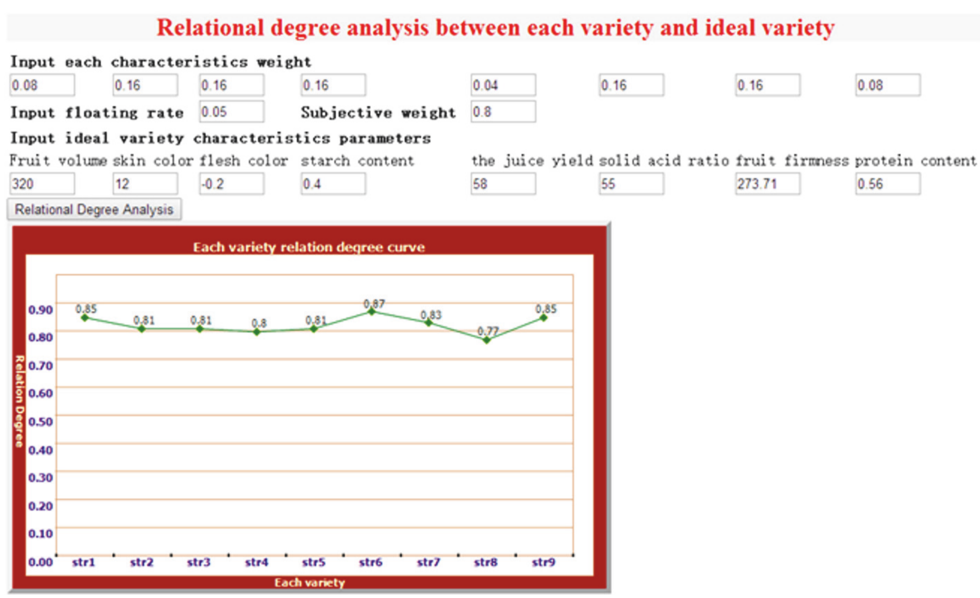

Figure 2: Improving curve.

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