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A Decision System for Commercial Products using Rough-Fuzzy Hybridization

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***Abstract*—The main aim of this paper is to develop a generalized decision system using rough set theory and fuzzy distance based approach for the determination of most saleable product in any commercial store. An information system has been presented in this article which consists of various factors like the price, stock available, discount rate available and the quality of the product which are essential for the evaluation of most saleable product. Rough set theory has been applied to generate fuzzy decision rules and hence to obtain the basic requirement criteria for the sale of the products. The customers have stated their opinion about the respective products that he or she has purchased linguistically. A relationship has been established between the purchased products of the respective customers and the customer opinions about the corresponding products using the fuzzy subset representation. The index of fuzziness of various customer opinions are measured and compared. Finally, a decision system has been developed using fuzzy distance approach for finding the most saleable product of the commercial store.**

***Index Terms*—Rough Sets, Fuzzy Sets, Soft computing, Fuzzy Distance Approach, Fuzzy Opinion matrix Approach.**

I. Introduction

Rough set theory was developed by Z. Pawlak [4], [7] on the assumption that with each object of the universe of discourse we associate some information, and the objects can be "seen" only through the accessible information. Hence, the object with the same information cannot be discerned and appear as the same. These results, thatindiscernible object of the universe forms clusters of indistinguishable objects which are often called *granules* or *atoms*.These granules are called *elementary sets* or *concepts*, and can be considered as elementary building blocks of knowledge. Elementary concepts can be combined into compound concepts, i.e. concepts that are uniquely defined in terms of elementary concepts. Any union of elementary sets is called a *crisp* set, and any other sets are referred to as *rough* (vague, imprecise). Consequently, each rough set has boundary-line cases, i.e., objects which cannot be with certainty classified as members of the set or its complement. Obviously crisp sets have no boundary-line elements at all. This means that boundary-line cases cannot be properly classified by employing the available knowledge. The main goal of rough set theoretic analysis is to synthesise approximation (upper and lower) of concepts from the acquired data. While fuzzy set theory assigns to each objects a grade of belongingness to represent an imprecise set, the focus of rough set theory is on the ambiguity caused by limited discernibility of objects in the domain of discourse. However, the rough set theory has been successfully applied to solve many real-life problems which involves decision making approaches [8], [9]. The main advantage of rough set theory is that it does not need any preliminary or additional information about data like probability in statistics and the grade of membership or the value of possibility in fuzzy set theory. It has been found by investigation that hybrid systems which consist of different soft computing tools combined into one system often improve the quality of the constructed system. Recently, rough sets and fuzzy sets have been integrated in soft computing framework, the aim being to develop a model of uncertainty stronger than either [6]. Therefore, Rough-fuzzy Hybridization decision systems have a significant potential.

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TABLE 1. STORE: AN EXAMPLE OF A DECISION TABLE

Items	Price (p)	Stock Available (s)	Discount rate Available (dr)	Quality (q)	Decision
X_1	Very High	More than Sufficient	High	Excellent	Profit
X_2	Very High	Insufficient	High	Average	Loss
X_3	Moderate	Insufficient	High	Good	Loss
X_4	High	Sufficient	High	Average	Profit
X_5	High	Less than Sufficient	High	Average	Loss
X_6	High	Sufficient	High	Excellent	Loss
X_7	Very High	Sufficient	Low	Good	Profit
X_8	Moderate	Insufficient	Low	Excellent	Loss

In this paper, Rough-Fuzzy hybridization has been used to develop a decision system for finding the most saleable product in any commercial store. In commercial stores, due to huge availability of different categories of products it is very difficult to trace or monitor the amount of sale of each product. An on-line feedback system is usually available where the customers are given opportunity to give the feedback about each product that he/she has purchased. Depending upon the feedback available from the customers the management authorities of the store gather information about the status of different products. An Information table which consists of set of objects called the universe and the various decisive factors (attributes) like Price, Stock available, Discount rate available and Quality of the product have been stated imprecisely along with the decision attributes with binary outcomes profit and loss. Due to granularity of knowledge some objects of interest cannot be discerned and appear as the same (or similar). Discernibility of the granulated objects in terms of attributes is then computed in the form of discernibility matrix. Using Rough set Theory, a number of decision rules are generated from the discernibility matrix which in turn forms the basic requirement criteria for the sale of the products. The customers have stated their opinion about the respective products that he/she has purchased linguistically. A fuzzy opinion matrix has been formed and the existing statistical decision making methods has been extended to derive a fuzzy decision set using Hurwicz's rule from which the product with higher grade of membership has to be selected.

II. Rough Set Theory

Let us present some of the basic concepts of Rough set theory which are related to this paper. For more details, one may refer to [4] and [5].

A. *Information Systems*

An Information system can be viewed as a pair Ŝ=<U, A>, or a function f: U × A→V, where U is a non-empty finite set of objects called the *Universe*, A is a non-empty finite set of *attributes*, such that a: U→ V_a for every a ∈ A. The set V_a is called the value set of a.

In many applications, there is an outcome of classification that is known. This is a posteriori knowledge is expressed by one distinguished attribute called *decision* attribute, the process is known as supervised learning. Information systems of this kind are called decision systems. A decision system is any information system of the form Â= (U, A ∪ {d}), where d ∉ A is the decision attribute. The elements of A are called conditional attributes or simply conditions. The decision attribute may take several values though binary outcomes are rather frequent. An Information (decision) system may be represented as an attribute-value (decision) table, where the rows are labeled by objects of the universe and columns by the attributes. Â = (U,{Price, Stock Available, Discount rate Available, Quality} ∪ {Decision}) for the sale of the products in any commercial store.

B. *Indiscernibility and Set Approximation*

A decision system (i.e. a decision table) expresses all the knowledge available about a system. This table may be unnecessarily large because it is redundant in at least two

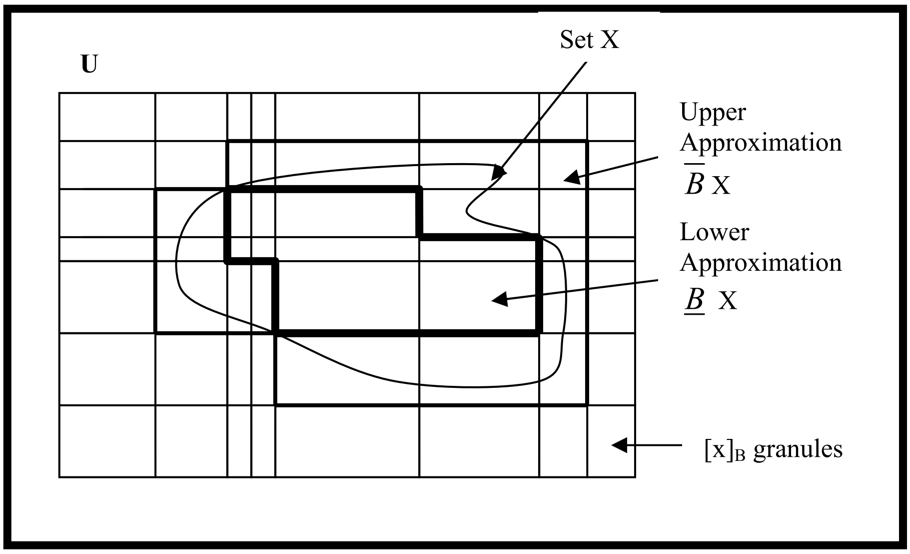

Fig 1. Rough Representation of a set with upper and lower approximations.

ways. The same or the indiscernible objects may be represented several times, or some of the attributes may be superfluous. With every subset of attributes B ⊆ A, one can easily associate an equivalence relation I_B on U: I_B = {(x, y) ∈ U: for every a ∈ B, a(x) = a(y)}. I_B is called B-indiscernibility relation. If (x, y)∈ I_B, the objects x and y are indiscernible from each other by attributes B. The equivalence classes of the partition induced by the B-indiscernibility relation are denoted by $[x]_B$. These are also known as *granules*. From the Table 1, if we consider the attribute set B = {Price, Stock Available}, the relation I_B defines the following partition of the universe.

$$I_B = I_{\{Price,\ Stock\ Available\}}$$
$$= \{\{x_3, x_8\}, \{x_4, x_6\}, \{x_5\}, \{x_1\}, \{x_2\}, \{x_7\}\}$$

Here $\{x_3, x_8\}$, $\{x_4, x_6\}$, $\{x_5\}$, $\{x_1\}$, $\{x_2\}$, $\{x_7\}$ are the granules obtained from the relation I_B.

The partition induced by the equivalence relation I_B can be used to build new subsets of the universe. Subsets that are most often of interest have the same value of the outcome attribute, i.e. they belong to the same class. It may happen, however, that a concept "*Loss*" in Table1 cannot be defined crisply using the available attribute. It is here that the notion of rough set emerges. Although we cannot delineate the concept crisply, it is possible to delineate the objects which definitely "belong" to the concept and those which definitely "do not belong" to the concept. Let Â= (U, A) be an information system and let $B \subseteq A$ and $X \subseteq U$. We can approximate X using only the information contained in B by constructing the B-lower and B-upper approximations of X, denoted as $\underline{B}$ X and $\overline{B}$ X respectively, where $\underline{B}X=\{x \mid [x]_B \subseteq X\}$ and $\overline{B}X=\{x \mid [x]_B \cap X \neq \emptyset\}$.The objects in $\underline{B}$ X can be certainly classified as the members of X on the basis of knowledge in B, and the objects in $\overline{B}$ X can only be classified as possible members of X on the basis of B. This is illustrated in Fig 1. If B={Price, Stock Available} and X is the concept *Loss*, then: $\underline{B}X=\{x_2, \{x_3, x_8\}, x_5\}$ and $\overline{B}X=\{x_2, \{x_3, x_8\}, \{x_4, x_6\}, x_5\}$. The set $BN_B(X) = \overline{B}X \Leftrightarrow \underline{B}X$ is called the B-boundary region of X and thus consists of those objects that we cannot decisively classify into X on the basis of knowledge of B. Thus, a set is said to be rough if the boundary region is non-empty otherwise crisp (boundary region is empty).

C. Reducts

Indiscernibility relation reduces the data by identifying equivalence classes, i.e. objects that are indiscernible, using the available attributes. Only one element of the equivalence class is needed to represent the entire class. Reduction can also be done by keeping only those attributes that preserve the indiscernibility relation and, consequently, set approximation. So, one is, in effect, looking for *minimal* set of attributes taken from the initial set A, so that the minimal set induce the *same* partition on the domain of A. In other words, the essence of the information remains intact and the superfluous attributes are removed.

TABLE 2 TWO DECISION TABLES OBTAINED BY SPLITTING THE STORE TABLE 1

Items	Price	Stock Available	Discount rate	Quality	Decision
X_1	Very High	More than Sufficient	High	Excellent	Profit
X_4	High	Sufficient	High	Average	Profit
X_7	Very High	Sufficient	High	Good	Profit

(a)

Item	Price	Stock Available	Discount rate	Quality	Decision
X_2	Very High	Insufficient	High	Average	Loss
X_3	Moderate	Insufficient	High	Good	Loss
X_5	High	Less than Sufficient	High	Average	Loss
X_6	High	Sufficient	High	Excellent	Loss
X_8	Moderate	Insufficient	Low	Excellent	Loss

(b)

The above sets of attributes are called *reducts*. Intersection of all reducts is called the *core*. Reducts have been clearly characterized in [5] by *discernibility matrices* and *discernibility functions*. Let us consider $U=\{x_1,\ldots,x_n\}$and $A=\{a_1,\ldots,a_n\}$ in the information system Ŝ=<U, A>. By the discernibility matrix M (Ŝ) of Ŝ is meant an n × n-matrix (symmetrical with empty diagonal) with entries C_{ij} Ŝ as follows:

$C_{ij} = \{a \in A: a(x_i) \neq a(x_j)\}$.

A discernibility function $f_{\hat{S}}$ is a function of *m* Boolean variables $\overline{a}_1,\ldots,\overline{a}_m$ corresponding to the attributes $a_1,\ldots,a_m$ respectively, and defined as follows:

$$f_{\hat{S}}(\overline{a}_1,\ldots,\overline{a}_m) = \bigwedge \{\bigvee (C_{ij}): 1 \leq i, j \leq n, j < i, C_{ij} \neq \emptyset\}$$

where $\bigvee C_{ij}$ is the disjunction of all variables $\overline{a}$ with $a \in C_{ij}$. It is seen in [5] that $\{a_1,\ldots,a_m\}$ is a reduct in Ŝ if and only $a_{i1} \cap \ldots \cap a_{ij}$ is a prime implicant (constituent of the disjunctive normal form) of $f_{\hat{S}}$.

D. Decision Rule Generation [18]

The Principle task in the method of rule generation is to compute reducts relative to a particular kind of Information system, i.e., the decision system. Let us consider Ŝ=<U, A> be a decision table, with A=C ∪ d, where d and C are the set of decision and condition attributes respectively. Let the value set of d be of cardinality l i.e. $V_d = \{d_1, d_2, ..., d_l\}$, representing l classes. Then we divide the decision table Ŝ=<U, A> into l tables such that $\hat{S}_i = < U_i, A_i >$ where i = 1, 2,…, l, corresponding to the l decision attributes $d_1, d_2, ..., d_l$, $U = U_1 \cup U_2 \cup .... \cup U_l$, and $A_i = C \cup \{d_i\}$. Let $\{x_{i1},...., x_{ip}\}$be the set of those objects of U_i that occur in $\hat{S}_i$, i = 1, 2,…, l. So, for each d_i-reduct $B=\{b_1, b_2,...., b_k\}$a discernibility matrix M_{di} (B) can be derived from the d_i- discernibility matrix as follows:

$C_{ij} = \{a \in B: a(x_i) \neq a(x_j)\}$, for i, j = 1, 2,…, n.

The dependency factor df_i for r_i is given by: $df_i = \frac{card(\, POS_{Bi}(d_i))}{card(U_i)}$, where $POS_{Bi}(d_i) = \bigcup_{X \in Idi} \underline{B}_i(X)$ and $\underline{B}_i(X)$ is the lower approximation of X with respect to B_i . B_i is the set of condition attributes occurring in the rule $r_i : d_i \leftarrow P_i$. $POS_{Bi}(d_i)$ is the positive region of

TABLE 3. DISCERNIBILITY MATRIX M_{PROFIT} FOR SPLITTING STORE DECISION TABLE (TABLE 2A)

Items	X_1	X_4	X_7
X_1		p, s, q	s, dr, q
X_4			p, dr, q
X_7			

class d_i with respect to the attributes B_i , denoting the region of class d_i that can be surely described by attributes B_i.The values of df_i lies in the interval [0,1], with the maximum and minimum values corresponding to the complete dependence and independence of d_i on B_i, respectively.

III. Fuzzy Distance Approach

Fuzzy Sets and Systems was developed by L.A. Zadeh [2], [3], and for more details about the Fuzzy Distance Based Approach one may refer to [13], [14], [17] & [22]. It can be seen from the Table 2(a) that though the decision attribute is profit but the various factors (attributes) that are taken into consideration like Price, Stock Available, Discount rate Available and Quality of the products have been stated imprecisely and are linguistic in nature. Consequently, these factors play a vital role for the evaluation of the most saleable product. Fuzzy decision making approach can be effectively utilized to tackle such problems where the information have not been stated precisely. Fuzzy approach is based on the premise that the key elements in human thinking are not just numbers but can be approximated to tables of fuzzy sets, or, in other words, classes of objects in which the transition from membership to non-membership is gradual rather than abrupt. In the ordinary set representation, if any product having high discount rate, the grade for that particular product's discount rate will be 1, otherwise 0. In fuzzy subset representation instead of giving abrupt values 1 or 0; gradual relative values have been given according to the availability of that particular product's discount rate. The basic requirements for the sale of the products have been stated imprecisely. It is given in Table 4.

TABLE 4.BASIC REQUIREMENTS FOR THE SALE OF THE PRODUCTS.

Requirements	Fuzzy values
1. Price	Very High
2. Stock Available	Sufficient
3. Discount rate Available	High
4. Quality	Excellent

The following fuzzy terms have been considered for Price:
1) Very High 2) High
3) Moderate 4) Low

The following Linguistic terms have been considered for the factors:

Stock Available:
1) More than Sufficient 2) Sufficient 3) Less than Sufficient 4) Insufficient

Discount rate Available:
1) High 2) Average 3) Low 4) Very Low

Quality:
1) Excellent 2) Good 3) Average 4) Fair

The Fuzzy Subset Representation for the basic Requirements factors of the products:
Price: 1/1.0 + 2/0.8 + 3/0.4 + 4/0.2
Stock Available: 1/1.0 + 2/1.0 + 3/0.6 + 4/0.2
Discount rate Available: 1/1.0 + 2/0.8 + 3/0.4 + 4/0.0
Quality: 1/1.0 + 2/0.8 + 3/0.6 + 4/0.2

The Fuzzy Subset representation for the various deciding Factors:

Price:
1) Very High: 1/1.0 + 2/0.8 + 3/0.4 + 4/0.2
2) High: 1/0.8 + 2/1.0 + 3/0.6 + 4/0.2
3) Moderate: 1/0.4 + 2/0.6 + 3/1.0 + 4/0.8
4) Low: 1/0.2 + 2/0.4 + 3/0.6 + 4/1.0

Stock Available:
1) More than Sufficient: 1/1.0 + 2/0.8 + 3/0.4 + 4/0.2
2) Sufficient: 1/0.8 + 2/1.0 + 3/0.6 + 4/0.2
3) Less than Sufficient: 1/0.2 + 2/0.6

+ 3/1.0 + 4/0.4

4) Insufficient: 1/0.0 + 2/0.4 + 3/0.6 + 4/1.0

Discount rate Available:

1) High: 1/1.0 + 2/0.8 + 3/0.4 + 4/0.0
2) Average: 1/0.8 + 2/1.0 + 3/0.6 + 4/0.2
3) Low: 1/0.2 + 2/0.6 + 3/1.0 + 4/0.4
4) Very Low: 1/0.0 + 2/0.4 + 3/0.6 + 4/1.0

Quality:

1) Excellent: 1/1.0 + 2/0.8 + 3/0.6 + 4/0.2
2) Good: 1/0.8 + 2/1.0 + 3/0.4 + 4/0.2
3) Average: 1/0.2 + 2/0.6 + 3/1.0 + 4/0.4
4) Fair: 1/0.2 + 2/0.4 + 3/0.6 + 4/1.0

With the above fuzzy subset representation, a decision system has been developed using the fuzzy distance approach and fuzzy opinion matrix to find the most saleable product in any commercial store. The customers give their opinion about the respective products that he/she has purchased linguistically. A fuzzy opinion matrix has been formed where the four customers gave their fuzzy opinion against the four products that he/she has purchased with respect to the factors Stock Available. It is given in Figure 2. The fuzzy Hamming distance between the basic requirement set of the sale of the products and the customer's opinion set for each product with respect to each factors has also been estimated.

$$
\begin{array}{c}
 \\
C_1 \\ C_2 \\ C_3 \\ C_4
\end{array}
\begin{array}{c}
\begin{array}{cccc} P_1 & P_2 & P_3 & P_4 \end{array} \\
\begin{pmatrix}
MS & LS & MS & IS \\
LS & S & MS & IS \\
S & S & S & LS \\
S & LS & S & LS
\end{pmatrix}
\end{array}
$$

Fig 2. Fuzzy Opinion Matrix

Where the symbol stands for:
MS – More than Sufficient, S – Sufficient, LS – Less than Sufficient, IS – Insufficient and C_1, C_2, C_3, C_4 are the Customer's opinion to the respective products P_1, P_2, P_3, P_4 that he /she has purchased from the store.

The fuzzy subset representation of these Linguistic terms has already been stated. The overall opinion about each product can be obtained by taking the intersection between customer opinions for that particular product. The overall opinions of customers with respect to the factor Stock Available are as follows:

So_1= 1/0.2 + 2/0.6 + 3/0.4 + 4/0.2

So_2 = 1/0.2 + 2/0.6 + 3/0.6 + 4/0.2

So_3 = 1/0.8 + 2/0.8 + 3/0.4 + 4/0.2

So_4 = 1/0.0 + 2/0.4 + 3/0.6 + 4/0.4

The Fuzzy decision set regarding Stock Available is obtained by using Hurwicz rule [15],

$$So_{Hur} = \alpha\, S_{Hi} + (1-\alpha)\, S_{Li}$$

where S_{Hi} are the highest grade & S_{Li} are the lowest grade for all the respective purchased products and α is the optimism-pessimism index and here we have taken the value of α =0.8

S_{Hi} = 1/0.8 + 2/0.8 + 3/0.6 + 4/ 0.4

S_{Li} = 1/0.0 + 2/0.4 + 3/0.4 + 4/0.2

Applying the values of S_{Hi} & S_{Li} in the above stated equation, we get

F_S = 1/0.64 + 2/0.72 + 3/0.56 + 4/0.36

The requirement set for the factor Stock Available is:

R= 1/1.0 + 2/1.0 + 3/0.6 + 4/0.2

The Fuzzy Hamming Distance [16] between the above two sets is given as:

$$\lambda(F_S,R) = \sum_{i=1}^{4} \left| \mu_{FE}(x_i) - \mu_R(x_i) \right| = 0.84$$

If the fuzzy opinion set is as close as to the basic requirement set, the Hamming distance will be very less.

Similarly, The Hurwicz decision set based on:

Price:

F_P = 1/0.68 + 2/0.72 + 3/0.56 + 4/0.68

$\lambda(F_P, R) = 1.04$

Discount rate Available:

F_{dr} = 1/0.64 + 2/0.72 + 3/0.56 + 4/0.32

$\lambda(F_{dr}, R) = 0.92$

Quality:

F_Q = 1/0.68 + 2/0.72 + 3/0.56 + 4/0.36

$\lambda(F_Q, R) = 0.60$

The overall fuzzy decision set has been estimated as follows:

$$F = \nu\,(F_S, F_P, F_{dr}, F_Q)$$
$$= 1/0.68 + 2/0.72 + 3/0.56 + 4/0.68$$

From the above decision set, product P_2 has the highest grade of membership. It is observed that product P_2 has exactly fit into the basic requirement set essential for the sale of the products and hence may be selected as the most saleable product of the store.

The Index of fuzziness can be defined with respect to the relative Hamming distance is defined as:

Index of Fuzziness, $\gamma = 2.0/n * \Delta\,(F_S, O_1)$

Where

$O_1 \equiv$ Ordinary subset nearest to fuzzy subset F_S

n ≡ Total number of elements contained in fuzzy Hurwicz opinion set

The membership function for the ordinary subset is defined by:

$$\beta_{O1}(x_i) = 0 \qquad \text{if} \quad \beta_E(x_i) \leq 0.5$$

$$\beta_{O1}(x_i) = 1 \qquad \text{if} \quad \beta_E(x_i) > 0.5$$

Hence the ordinary subset for fuzzy Hurwicz opinion set with respect to the factor Stock Available is given as:

$$O_1 = [1 \quad 1 \quad 1 \quad 0]$$

The Index of fuzziness,

$$\gamma = 2.0/4.0 * [0.32 + 0.28 + 0.44 + 0.36] = 0.7$$

Similarly, the indices of fuzziness have been estimated for the overall opinion of the customers with respect to the various requirement factors and found to be approximately equal to 0.7

IV. Conclusion

This paper describes a technique for finding the most saleable commercial product based on Rough-Fuzzy Hybridization. The Rough Set Theory identifies the relationships that would not be found using statistical methods and also allows both quantitative and qualitative data that offers straightforward interpretations to obtain results. Rough set approach to data analysis is characterized by means of approximations, or equivalently by decision rules induced by the data which are presented in the form of decision table. This paper is no more an exceptional case. Here, also we have presented a decision table Store Table1 consisting of various attributes which play a key role in decision making analysis. In this paper, rough set theory has been applied to obtain the basic requirements for the sale of the products. Then, the basic requirements of the products and the customer's opinion about the purchased products are considered as fuzzy variables since the attribute values of the various conditional attributes in the decision table are Linguistic in nature. A fuzzy decision system has been developed using fuzzy distance and fuzzy opinion matrix approaches. A fuzzy decision set has been formulated which indicates the relative merits of all products from which a particular product with highest grade of merits has to be selected.

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