Annals of **F**uzzy **M**athematics and **I**nformatics
Volume 5, No. 1, (January 2013), pp. 35–44
ISSN: 2093–9310 (print version)
ISSN: 2287–6235 (electronic version)
http://www.afmi.or.kr

On soft multi sets

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Received 18 January 2012; Accepted 5 May 2012

Abstract. Theory of soft set and multiset are important mathematical tool to handle uncertainties. Soft set theory was proposed by Molodtsov as a general framework for reasoning about vague concepts. This paper hopefully initiate the novel concept called soft multisets which is a mapping from parameter set to whole multisubset of universal set and points out different set theoretic operations on it. Discussion on AND, OR operator on soft multiset is made and DeMorgan's laws is also proved. It is also shown a relationship between soft multi sets and muti-valued information system. An application of soft multi set in decision making problem is also discussed.

2010 AMS Classification: 03E70

Keywords: Soft set, Soft multiset, Tabular representation, Muti-valued information system

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1. Introduction

The mathematical modeling and manipulating of various types of uncertainties has become an issue of great relevance in the solution of complicated problems arising in a wide range of different areas such as engineering, economics, environmental science, medicine and social sciences. Although a number of mathematical models like probability theory, fuzzy sets [18], rough sets [11] and interval mathematics [4] are well-known and often effective tools for dealing with uncertainty, each of them has distinguished advantages as well as certain inherent limitations. One major weakness shared by these theories is possibly the inadequacy of parametrization tools as pointed out by Molodtsov [9]. In 1999, Molodtsov [9] initiated soft set theory as a generic mathematical approach to modelling vagueness and uncertainty, which is free from the difficulties affecting the above mentioned methods. The traditional soft set is a mapping from parameter to the crisp subset of universe.

Many works have been done on hybrid types of soft set such as fuzzy soft set, soft fuzzy sets, rough soft sets, soft rough sets. In Xibei yang et al. [16] the standard soft set theory is expanded to a fuzzy one in which the fuzzy character of parameters in real world is taken into consideration. Feng et al.[2] have investigated the problem of combing soft sets with fuzzy sets and rough sets. M I Ali [10] discussed the concept of an approximation space associated with each parameter in a soft set and an approximation space associated with the soft set is defined. Also, based on a novel granulation structures called soft approximation spaces, Feng Feng [2] introduced soft rough approximations and soft rough sets.

Tutut Herawan [5] presented the notion of multisoft sets representing a multivalued information system. The idea was based on the decomposition of a multi-valued information system into binary-valued information systems.The concept of topology on soft set is studied by researchers [12,13,15]. Y Jiang et al. [17]present an adjustable approach to intuitionistic fuzzy soft sets based decision making by using level soft sets of intuitionistic fuzzy soft sets. Using rough set theory, Z Zhang[19] proposes a novel approach to intuitionistic fuzzy soft set based decision making problems.

In this paper discussion is going on soft multisets. Usually a classical soft set is a mapping from a parameter set to power set of universal set. In this case univeral set is a crisp set. But in many practical situations some situations may occur, where the respective counts of objects in the universe of discourse are not single. With this motivation in mind we define soft multisets, in which the universal set is a multiset. It maps parameter set to power whole multiset of universal set. In real life situations we have lots of examples for soft multisets. For details studies on multisets, one can refer to [3,6,14]

The organization of paper is as follows: In section 2 basic notions about soft set and multi set is reviewed. Section 3 focuses on the definition of soft multisets. Also union, intersection, AND, OR and Compliment operations are defined. De Morgan's laws based on soft multiset is proved. Absolute soft multi set and Null soft multiset are defined and proved some set theoretic results based on it. In section 4 comprise two subsections. In the first subsection it is derived a relationship between soft multisets and muti-valued information system. In the second subsection, the algorithm suggested by Maji et al. in decision making problems is extended to soft multi set context.

2. Preliminaries

In the current section we recollect the basic definitions and notations as introduced by Molodtsov [9] and Maji et.al. [7] . We also recall definition of multiset and for further details and background see [3,8].

Definition 2.1. Let U be an initial universe set and E be a set of parameters. Let P (U) denotes the power set of U and A $\subseteq$ E. A pair (F, A) is called a soft set over U, where F is a mapping given by F: A $\rightarrow$P (U).

Definition 2.2. For two soft sets (F, A) and (G, B) over a common universe U, we say that (F, A) is a soft subset of (G, B) if

i: A $\subseteq$ B, and

ii: $\forall\ \varepsilon \in$, F (ε) is subset of G (ε).

We write (F,A) $\tilde{\subseteq}$(G,B)
Also (F, A) is said to be a soft super set of (G, B), if (G, B) is a soft subset of (F, A). We denote it by (F,A) $\tilde{\supseteq}$(G,B).
Two soft sets (F, A) and (G, B) over a common universe U are said to be soft equal if (F, A) is a soft subset of (G, B) and (G, B) is a soft subset of (F, A)

Definition 2.3. Let $A = \{e_1, e_2, e_3, .., e_n\}$ be a set of parameters. The NOT set of A denoted by $\rceil\ A$ is defined by $\rceil\ A = \{\rceil\ e_1, \rceil\ e_2, \rceil\ e_3, .., \rceil\ e_n\}$, where $\rceil\ e_i = note_i, \forall$ i=1,2à.. n .

Definition 2.4. The complement of a soft set (F, A) is denoted by $(F, A)^c$ and is defined by $(F, A)^c = (F^c, \rceil\ A)$ where $F^c : \rceil\ A \to P(U)$ is a mapping given by $F^c(a) = U - F(a), \forall a \in A$.

Let us call F^c to be the soft complement function of F. Clearly $(F^c)^c$ is the same as F and $((F, A)^c)^c = (F, A)$.

Proposition 2.5. *If A and B are two sets of parameters then we have the following*

i: $\rceil\ (\rceil\ A) = A$
ii: $\rceil\ (A \cup B) = \rceil\ A \cup \rceil\ B$
iii: $\rceil\ (A \cap B) = \rceil\ A \cap \rceil\ B$

Definition 2.6. An mset M drawn from the set X is represented by a function Count M or C_M defined as $C_M : X \to N$ where N represents the set of non negative integers. The word "multiset" often shortened to "mset".

Definition 2.7. Let M_1 and M_2 be two msets drawn from a set X. An mset M_1 is a submset of M_2, ($M_1 \subseteq M_2$) if $C_{M_1}(x) \leq C_{M_2}(x)$ for all $x \in X$.

Definition 2.8. The union of two msets M_1 and M_2 drawn from a set X is an mset M denoted by $M = M_1 \cup M_2$ such that $x \in X, C_M(x) = \max\{C_{M_1}(x), C_{M_2}(x)\}$.

Definition 2.9. The intersection of two msets M_1 and M_2 drawn from a set X is an mset M denoted by $M = M_1 \cap M_2$ such that $x \in X, C_M(x) = \min\{C_{M_1}(x), C_{M_2}(x)\}$.

Definition 2.10. A submset N of M is a whole submset of M with each element in N having full multiplicity as in M. i.e.,$C_N(x) = C_M(x)$ for every x in N.

Definition 2.11. Let $[X]^m$ denotes the set of all msets whose elements are in X such that no element in the mset occurs more than m times. Let $M \in [X]^m$ be an mset. The power whole mset of M denoted by *PW(M)* is defined as the set of all whole submsets of M. i.e., for constructing power whole submsets of M, every element of M with its full multiplicity behaves like an element in a classical set. The cardinality of *PW(M)* is 2^n where n is the cardinality of the support set (root set) of M.

Notation 1 Let M be an mset from X with x appearing n times in M. It is denoted by $x \in {}^n M$. $M = \{k_1/x_1, k_2/x_2, .., k_n/x_n\}$ where M is an mset with x_1 appearing k_1 times, x_2 appearing k_2 times, and so on.

	e_1	e_2.......	e_m
u_1	u_{11}	u_{12}	u_{1m}
u_2	u_{21}	u_{22}	u_{2m}
..	..	......	..
u_n	u_{n1}	u_{n2}	u_{nm}

3. Soft multisets

Definition 3.1. Let U be universal mset and E be set of parameters. Then an ordered pair (F, E) is called a soft multi set where F is a mapping given by $F : A \rightarrow$ *PW(U)*

Example 3.2. Let U be universal mset consist of balls under consideration.
$U = \{k_1/b_1, k_2/b_2, k_3/b_3, k_4/b_4, k_5/b_5, k_6/b_6\}$ where k_i denotes the multiplicity of ball b_i. Let A = {black ,red, blue}. Then the soft multi set (F, A) defined below gives different colors of balls under consideration.

$$F(black) = \{k_2/b_2, k_3/b_3\}$$
$$F(red) = \{k_1/b_1, k_4/b_4\}$$
$$F(blue) = \{k_5/b_5, k_6/b_6\}$$

Note that for the approximations "$blackballs = \{k_2/b_2, k_3/b_3\}$" the multiplicity of element is same as those of the universal mset. Here the approximation set is a multiset.

Tabular representation of soft multi sets

Consider a multi soft set where $U = \{u_1/k_1, u_2/k_2, ...u_n/k_n\}$ and $A = \{e_1, e_2, ...e_m\}$. Then we represent a soft multi set in tabular form as follows. This style of representation is most useful for storing soft multi set in computer. Here

$$Here \quad u_{ij} = k_i \text{ if } u_i \in {}^{k_i}F(e_j)$$
$$= 0 \quad otherwise$$

Definition 3.3. For two soft multisets (F,A) and (G,B) over a common universe U we say that (F,A) is soft multi subset of (G,B) if

i: A $\subseteq$ B, and
ii: $\forall\ \varepsilon \in$ A, F (ε) is multi subset of G (ε) .

Example 3.4. Consider soft multiset (G,B) defined on U given in above example where $B = \{blue, red\}$
$G(blue) = \{k_5/b_5\}$
$G(red) = \{k_4/b_4\}$
Then (G,B) is soft multi subset of (F, A)

Definition 3.5. Soft multisets (F, A) and (G,A) over a common universe U are said to be equal if (F,A) is soft multi subset of (G,B) and (G,B) is soft multi subset of (F, A).

Definition 3.6. Let M be a multiset. Then the relative compliment of a whole submset M_1 of M is given by $M_1^r = m_i/x_i$ where $C_M(x_i) = 0$ for every $x_i$in M_1 and m_i is the count of x_i in M.

Example 3.7. Let

$$M = \{x_1/k_1, x_2/k_2, x_3/k_3, x_4/k_4, x_5/k_5\}$$
$$M_1 = \{x_2/k_2, x_4/k_4, x_5/k_5\}$$

Then the relative compliment of M_1 is given by $M_1^r = \{x_1/k_1, x_3/k_3\}$

In the following definition the compliment of multiset is taken as relative compliment.

Definition 3.8. If (F,A) and (G,A) over a common universe U are soft multisets then (F,A) AND (G,A) denoted by $(F, A) \wedge (G, B)$ is defined as $(F, A) \wedge (G, B) = (H, A \times B)$ where $H(a, b) = F(a) \cap G(b)$. Here $\cap$ denotes the union of two multisets F(a) and G(b).

Definition 3.9. If (F,A) and (G,A) over a common universe U are soft multisets then (F,A) OR (G,A) denoted by $(F, A) \vee (G, B)$ is defined as $(F, A) \vee (G, B) = (H, A \times B)$ where $H(a, b) = F(a) \cup G(b)$. Here $\cup$ denotes the union of two multisets F(a) and G(b).

Definition 3.10. The compliment of a soft multiset (F,A) is denoted by $(F, A)^c$ and is defined by $(F, A)^c = (F^c, \rceil A)$ where $F^c(\rceil a) = F^r(a)$ for every $\rceil a \in \rceil A$.

We see that the following type of DeMorgan's laws are true in the soft multisets case also.

Definition 3.11. Intersection of two soft multisets (F,A) and (G,A) over a common universe U is the soft multi set (H, C), where C = A$\cup$ B, and $\forall$ e $\in$ C

$$H(e) = \begin{cases} F(e), & if \quad e \in A - B, \\ G(e), & if \quad e \in B - A, \\ F(e) \cap G(e), & if \ \ e \in A \cap B. \end{cases}$$

Proposition 3.12. *Let (F,A) and (G,A) be two soft multisets over a common universe U .Then*

i: $[(F, A) \vee (G, B)]^c = (F, A)^c \wedge (G, B)^c$
ii: $[(F, A) \wedge (G, B)]^c = (F, A)^c \vee (G, B)^c$

Proof. suppose that $(F, A) \vee (G, B) = (H, A \times B)$. Therefore $[(F, A) \vee (G, B)]^c = (H, A \times B)^c = (H^c, \rceil A \times \rceil B)$.

$$\begin{aligned} \text{Then} \quad H^c(\rceil a, \rceil b) &= H^r(a, b) \\ &= (F(a) \cup G(b))^r \\ &= F^r(a) \cap G^r(b) \\ &= F^c(\rceil a) \cap G^c(\rceil b) \end{aligned}$$

Now

$$\begin{aligned} (F, A)^c \wedge (G, B)^c &= (F^c, \rceil A) \wedge (G^c, \rceil B) \\ &= (K, \rceil A \times \rceil B) \text{ where } K(\rceil a, \rceil b) = F^c(\rceil a) \cap G?^c(\rceil b) \\ &= (H^c, \rceil A \times \rceil B) \end{aligned}$$

(ii) Same as above

□

Definition 3.13. Union of two soft multisets (F, A) and (G, B) over the common universe U is the soft multiset (H, C), where C = A∪ B, and ∀ e ∈ C

$$H(e) = \begin{cases} F(e), & if \quad e \in A - B, \\ G(e), & if \quad e \in B - A, \\ F(e) \cup G(e), & if \; e \in A \cap B. \end{cases}$$

We write (F,A) $\tilde{\cup}$(G,B)

Definition 3.14. A soft multiset (F, A) over universe U is said to be absolute soft multiset denoted by $\widetilde{A}$ if for all$a \in A$,F(a)=U.

Definition 3.15. A soft multiset (F, A) over universe U is said to be null soft multiset denoted by $\widetilde{\phi}$ if for all $a \in A, F(a) = \phi$

Proposition 3.16. *Let (F,A) and (G,B) be two soft multisets over a common universe U. Then*

i: $[(F,A)\,\widetilde{\cup}\,(G,B)]^c = (F,A)^c\,\widetilde{\cap}\,(G,B)^c$
ii: $[(F,A)\,\widetilde{\cap}\,(G,B)]^c = (F,A)^c\,\widetilde{\cup}\,(G,B)^c$

Proof. Suppose that $(F,A)\,\widetilde{\cup}\,(G,B) = (H, A \times B)$
Then $[(F,A)\,\widetilde{\cup}\,(G,B)]^c = (H^c, \rceil\, A \cup \rceil\, B)$ where $H^c(\rceil\, a) = H^r(a)$.
By definition,

$$H(c) = \begin{cases} F(c), & if \quad c \in A - B, \\ G(c), & if \quad c \in B - A, \\ F(c) \cup G(c), & if \; c \in A \cap B. \end{cases}$$

Thus we have

$$H^c(\rceil\, c) = \begin{cases} F^r(c), & if \quad \rceil\, c \in \rceil\, A - \rceil\, B, \\ G^r(c), & if \quad \rceil\, c \in \rceil\, B - \rceil\, A, \\ (F(c) \cup G(c))^r, & if \; \rceil\, c \in \rceil\, A \cap \rceil\, B. \end{cases}$$

i.e.

$$H^c(\rceil\, c) = \begin{cases} F^r(c), & if \quad \rceil\, c \in \rceil\, A - \rceil\, B, \\ G^r(c), & if \quad \rceil\, c \in \rceil\, B - \rceil\, A, \\ F(c)^r \cup G(c)^r, & if \; \rceil\, c \in \rceil\, A \cap \rceil\, B. \end{cases}$$

Moreover, let $(F,A)^c\,\widetilde{\cap}\,(G,B)^c = (F^c, \rceil\, A)\,\widetilde{\cap}\,(G^c, \rceil\, B) = (K, \rceil\, A \cup \rceil\, B)$
Then

$$K(\rceil\, c) = \begin{cases} F^c(\rceil\, c), & if \quad \rceil\, c \in \rceil\, A - \rceil\, B, \\ G^c(\rceil\, c), & if \quad \rceil\, c \in \rceil\, B - \rceil\, A, \\ F^c(\rceil\, c) \cup G^c(\rceil\, c), & if \; \rceil\, c \in \rceil\, A \cap \rceil\, B. \end{cases}$$

Since H^c and K are indeed the same set valued mapping, we conclude that $[(F,A)\widetilde{\cup}(G,B)]^c = (F,A)^c \,\widetilde{\cap}\, (G,B)^c$ as required.
(ii) Similar as above.
The following results are obvious.

□

Proposition 3.17. **i:** $(F,A)\,\widetilde{\cup}\,(F,A) = (F,A)$
ii: $(F,A)\,\widetilde{\cup}\,(F,A) = (F,A)$
iii: $(F,A)\,\widetilde{\cup}\,\phi = (F,A)$

4. Soft multisets in information systems and decision making problems

4.1. **Soft multisets and multi valued Information systems.** It has been shown that there is compact connections between soft sets and information systems. Soft sets are a class of special information system. A classical soft set is a binary valued information system. From the concept and the example of soft multisets given in the previous section it can be shown that a soft multi set is a muti-valued information system. The following gives the precise definition of multi-valued information system.

Definition 4.1. A multi-valued information system is a quadruple S = (X, A, f, V) where X is a non-empty finite set of objects, A is a non-empty finite set of attributes, $V = \bigcup_{a\in A} V_a$ where V is the domain (value set) set of attribute a which has multi-value ($|V_a| \geq 3$) and $f : U \times A \to V$is a total function such that $f(u,a) \in V_a$ for every $(u,a) \in X \times A$.

Proposition 4.2. *If (F, A) is soft multiset over universe U then (F, A) is a muti-valued information system.*

Proof. Let (F, A) be a soft multiset. We define a mapping f where $f : U \times A \to V$ as $f(u,a) = C_{F(a)}(u)$ where C is the count of element u in the multiset F(a). Hence $V = \bigcup_{a\in A} V_a$ where V_a is the set of all counts of u in F(a). Then the multi-valued information system (U,A,f,V) represents the soft multiset (F, A). □

Example 4.3. Consider $U = \{k_1/b_1, k_2/b_2, k_3/b_3, k_4/b_4, k_5/b_5, k_6/b_6, k_7/b_7\}$ and A= {cheap, expensive, average}
Then $F(cheap) = \{k_1/b_1, k_3/b_3, k_7/b_7\}$
$F(expensive) = \{k_2/b_2, k_4/b_4\}$, $F(average) = \{k_5/b_5, k_6/b_6\}$
Then the soft multiset defined above represents the cost of balls.
Then the quadruple S = (X, A, f, V) corresponding to the soft multiset given above is a mutivalued information system. Here X = U and A is the same set of parameters as in soft multi set and $V_{cheap} = \{k_1, k_3, k_7\}$, $V_{expensive} = \{k_1, k_3, k_7\}$, and $V_{average} = \{k_5, k_6\}$. For the pair $(b_1, cheap)$ we have $f(b_1, cheap) = k_1$. Similarly we obtain the value of other pairs.

We can construct a information table representing soft multiset (F,A) defined above as follows.

Thus according to the above result it is seen that soft multisets are muti-valued

	cheap	expensive	average
b_1	k_1	0	0
b_2	0	k_2	0
b_3	k_3	0	0
b_4	0	k_4	0
b_5	0	0	k_5
b_6	0	0	k_6
b_7	k_7	0	0

information systems. However, it is obvious that multi-valued information systems are not necessarily soft mutisets.

4.2. **A soft multiset approach in decision making problem.** The problem of decision making in an imprecise environment has found paramount importance in recent years. Maji et al. [13] introduce the definition of reduct-soft-set and describe the application of soft set theory to a decision-making problem using rough set approach. In this section Maji approach is extended in soft multi set case.
Consider a problem for retail shop keeper to select a particular type of bags satisfying his demand.
Let $U = \{10/b_1, 15/b_2, 7/b_3, 8/b_4, 18/b_5, 11/b_6, 10/b_7\}$ and A= {leather, cheap, big, discount} be set of parameters. Consider a soft multiset describing the different types of bags under consideration and is given by $F(leather) = \{10/b_1, 15/b_2, \}$, $F(cheap) = \{15/b_2, 7/b_3, 8/b_4\}$, $F(big) = \{10/b_1, 15/b_2, 7/b_3, 8/b_4\}$, $F(discount) = \{18/b_5, 11/b_6, 10/b_7\}$
Suppose that the shopkeeper would like to buy a set of bags according to the choice of parameters say B=leather, cheap, discount Here the demand of bags are same as those of availability. To solve the problem consider the following theoretical characterizations of soft set theory suggested by Maji et.al [8].

Definition 4.4. IF (F, A) is a soft set and let $B \subseteq A$. If B is a reduct of A, then the soft set (F, B) is called the reduct soft set of the soft set (F, A).

Definition 4.5. IF (F, A) is a soft multi set over U ,the weighted choice value of an object $u_i \in U$ is c_i given by $c_i = \sum_j d_{ij}$ where $d_{ij} = w_i \times u_{ij}$. Here w_i is weighs imposed on to the parameters by the buyer and u_{ij} is the count of u_i in $F(e_j)$.

The revised algorithm for the selection of bags

Step 1: Input the soft multi set (F,A)

Step 2: Input the set B of choice parameters of shopkeeper which is a subset of A
Step 3: Find all reduct soft sets of (F, B)
Step 4: Choose one reduct soft set say (F, Q) of (F, B),
Step 5: Find weighted table of the soft set (F, Q) according to the weights decided by shopkeeper.
Step 6: Find k, for which $c_k = \max_i c_i$

Let us solve the given problem using the above revised algorithm. The reduct of B is B itself. Suppose the shopkeeper put the weights as follows: leather =0 .4, cheap = 0.8, discount = 0.5

Bags	leather	Cheap	Discount	Choice value
b_1	10	0	0	4
b_2	15	15	0	18.0
b_3	0	7	0	6.4
b_4	0	8	0	6.4
b_5	0	0	18	9
b_6	0	0	11	5.5
b_7	0	0	10	5

From the weighted table the maximum choice value is 11.6 and therefore shopkeeper can buy 15 number of the bag b_2. In case the demand K of the item is less than the availability, then use the same soft multi set with count of each object should be decreased by the amout K and follow the same algorithm.

5. Conclusion

The soft set theory propositionositionosed by Molodtsov offers a general mathematical tool for dealing with uncertain or vague objects. In the present paper, soft multi set is defined which is a mapping from parameter set to powerwhole multiset. More over fundamental set theoretic operation such as union , intersection,compliment are also defined with and proved some results. Further AND, OR operations on soft sets are extended in soft multisets case. De Morgans law with respect to AND,OR operations are also investigated. It is shown that soft multi sets are special type of information system known as multi-valued information system. Soft multi sets are applied in decision making problems. Further study will be needed to establish whether the notions put forth in this paper may lead to a fruitful theory.

Acknowledgements. The first author acknowledge the financial assistance given by the Council of Scientific and Industrial Research, Government of India throughout the preparation of this paper.

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