Subtraction of soft matrices

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Abstract. In this paper, we introduce subtraction operation notation on the soft matrix of size $m \times n$ with its entry on the set $\{0, 1\}$. In addition, we studied the characteristics of subtraction operations over intersection and union operations on soft matrices. The result shows the distributive law of subtraction operations over intersection and union operations on the soft matrix. Finally, we discuss the characteristics of De Morgan's law analogous to set theory.

1. Introduction
The development of research in mathematics over time is increasingly varied, ranging from continuing previous research or correcting previous research to becoming a better study. Similarly, the theory of soft sets popularized by Molodtsov [1] is follow-up research and, at the same time, corrects the idea of fuzzy sets introduced by Zadeh [2]. In contrast, Zadeh's theory of fuzzy sets popularized is a correction of the idea of sets invented by Georg Cantor [3]. The soft set theory is a frame of the fuzzy set theory, which deals with uncertainty parametrically. The soft set theory is a collection of intuitively parameterized sets because the set limits depend on parameters. Formally, the group is a couple $(\Delta, \mathcal{N})$ such that $\Delta$ is a mapping of parameters $\mathcal{N}$ to the muster of all subsets of the universe $\mathcal{U}$.

Sourced from the definition of the soft set $(\Delta, \mathcal{N})$ of the $\mathcal{U}$ universe, many researchers apply it to other fields, between [4–9]. One of the products of the soft set studied by [10,11,20–23,12–19] is a soft matrix of size $m \times n$ with entries in the form of elements at $\{0, 1\}$. This paper aims to introduce the notation of the subtraction operation of the soft matrices. Furthermore, we will study the characteristics of intersection and union operations of subtraction operations, the distributive law of subtraction operations over intersection and union operations, as well as De Morgan's law of subtraction operations that are similar to set theory.

2. Method
We keep in mind some of the foundation definitions, and results wore in the sequel in this segment. For details, we refer to [1,10,24–27].

We’ll give some notation: $\mathcal{U}$ states the set of universes, $P(\mathcal{U})$ says the set of all subsets of $\mathcal{U}$, and $\mathcal{N}$ and $\mathcal{J}$ are sets of parameters where $\mathcal{N} \subseteq \mathcal{J}$.

Definition 2.1. A couple $(\Delta, \mathcal{N})$ is termed the soft set of $\mathcal{U}$ if $\Delta$ is the function from $\mathcal{N}$ to a collection of all subsets from $\mathcal{U}$, i.e.

$$\Delta : \mathcal{N} \to P(\mathcal{U})$$ (1)
In this case, it is termed the estimate of the function of the set \((\Delta, N)\). For each \(\eta \in N\), the set \(\Delta(\eta)\) is termed \(\eta\)-approximation of elements from the set \((\Delta, N)\) relating to the \(\eta \in N\) parameter. In addition, we can write the set \((\Delta, N)\) of \(H\) as:

\[
(\Delta, N) = \{ (x, \Delta(x)) | x \in N, \Delta(x) \in P(H) \}.
\]

**Definition 2.2.** Let \((\Delta, N)\) be a soft set of \(H\).

i). A subset of \(H \times N\) can be defined by

\[
\kappa = \{ (x, \eta) | \eta \in N, x \in \Delta(\eta) \}.
\]

The set \(\kappa\) is termed the relationship form \((\Delta, N)\).

ii). The characteristic function \(\kappa\) is expressed by:

\[
\chi_c : H \times N \to [0,1], \quad (x, \eta) \in \kappa \implies 1, \quad (x, \eta) \notin \kappa \implies 0.
\]

iii). If \(H = \{u_1, \ldots, u_m\}, \ N = \{\eta_1, \ldots, \eta_n\}\) then \(\kappa\) can be given in the following table

| \kappa | \eta_1 | \eta_2 | \ldots | \eta_n |
|---|---|---|---|---|
| \(u_1\) | \(\chi_c(u_1, \eta_1)\) | \(\chi_c(u_1, \eta_2)\) | \ldots | \(\chi_c(u_1, \eta_n)\) |
| \(u_2\) | \(\chi_c(u_2, \eta_1)\) | \(\chi_c(u_2, \eta_2)\) | \ldots | \(\chi_c(u_2, \eta_n)\) |
| \ldots | \ldots | \ldots | \ldots | \ldots |
| \(u_m\) | \(\chi_c(u_m, \eta_1)\) | \(\chi_c(u_m, \eta_2)\) | \ldots | \(\chi_c(u_m, \eta_n)\) |

iv). If \(\rho_j = \chi_c(u_1, \eta_j)\), then a matrix is defined

\[
\begin{pmatrix}
\rho_{11} & \ldots & \rho_{1n} \\
\vdots & \ddots & \vdots \\
\rho_{m1} & \ldots & \rho_{mn}
\end{pmatrix}
\]

Matrix \([\rho_j]\) is termed the soft matrix of size \(m \times n\) of \((\Delta, N)\) over \(H\). We will symbolize the set of all \(m \times n\) soft matrices of \(H\) as \(S_{m,n}^{H}\).

In the following, we will present the types of soft matrices based on the entries of the soft matrix constituents.

**Definition 2.3.** Suppose that \([\rho_j] \in S_{m,n}^{H}\). Then \([\rho_j]\) is termed

(i). A zero soft matrix, denoted by \([0]\) if and only if \(\rho_{ij} = 0\) for any \(i\) and \(j\).

(ii). universal soft matrix, represented by \([1]\), i.e., \(\rho_{ij} = 1\) for any \(i\) and \(j\).

**Definition 2.4.** Let’s say \([\rho_j]\) and \([c_j]\) are \(m \times n\) size soft matrices.

(i). The union of \([\rho_j]\) and \([c_j]\), denoted \([\rho_j] \cup [c_j]\), is defined by \([\rho_j] \cup [c_j] := [\rho_j \lor c_j]\) for any \(i\) and \(j\).

(ii). The intersection of \([\rho_j]\) and \([c_j]\), denoted \([\rho_j] \cap [c_j]\), is defined by \([\rho_j] \cap [c_j] := [\rho_j \land c_j]\) for any \(i\) and \(j\).

(iii). The complement \([\rho_j]\), denoted \([\overline{\rho_j}]\), is defined by \([\overline{\rho_j}] := [1 - \rho_j]\) for any \(i\) and \(j\).

(iv). The subtraction of \([\rho_j]\) and \([c_j]\), denoted \([\rho_j] - [c_j]\), defined by \([\rho_j] - [c_j] := [\rho_j \land (1 - c_j)]\) for any \(i\) and \(j\).
3. Result and Analysis

**Theorem 3.1** Let $[\rho_{ij}] \in S^m_{m \times n}$. Then

i). $[\rho_{ij}] - [\rho_{ij}] = [0]$,

ii). $[\rho_{ij}] - [0] = [\rho_{ij}]$,

iii). $[0] - [\rho_{ij}] = [0]$.

In global, the subtraction of soft matrices does not apply the commutative law.

**Theorem 3.2** Let $[\rho_{ij}], [\delta_{ij}] \in S^m_{m \times n}$. Then $[\rho_{ij}] - [\delta_{ij}] = [\delta_{ij}] - [\rho_{ij}]$.

**Proof.**

Let $[\rho_{ij}], [\delta_{ij}] \in S^m_{m \times n}$. Then for any $i$ and $j$,

$$[\rho_{ij}] - [\delta_{ij}] = [\rho_{ij} \land (1 - \delta_{ij})]$$

$$= [(1 - \delta_{ij}) \land \rho_{ij}]$$

$$= [(1 - \delta_{ij}) \land (1 - (1 - \rho_{ij}))]$$

$$= [\delta_{ij}] - [\rho_{ij}].$$

In the following theorem, the subtraction condition for a disjoint soft matrix is analogous to set theory.

**Theorem 3.3** Let $[\rho_{ij}], [\delta_{ij}] \in S^m_{m \times n}$. If $[\rho_{ij}] \cap [\delta_{ij}] = [0]$ then $[\rho_{ij}] - [\delta_{ij}] = [\rho_{ij}]$.

**Proof.**

Since $[\rho_{ij}] \cap [\delta_{ij}] = [0]$ and $\rho_{ij}, \delta_{ij} \in \{0,1\}$ for any $i$ and $j$, we get $[\delta_{ij}] = [\overline{\rho_{ij}}]$. Therefore,

$$[\rho_{ij}] - [\delta_{ij}] = [\rho_{ij}] - [\overline{\rho_{ij}}] = [\rho_{ij} \land (1 - (1 - \rho_{ij}))] = [\rho_{ij}].$$

From Theorem 3.3, the following theorem conditions are obtained.

**Theorem 3.4** Let $[\rho_{ij}], [c_{ij}], [\delta_{ij}] \in S^m_{m \times n}$. If $[c_{ij}] \cap [\delta_{ij}] = [0]$ and $[c_{ij}] \cup [\delta_{ij}] = [\rho_{ij}]$ then $[\rho_{ij}] - [\delta_{ij}] = [c_{ij}]$.

**Proof.**

Since $[c_{ij}] \cap [\delta_{ij}] = [0]$, $[c_{ij}] \cup [\delta_{ij}] = [\rho_{ij}]$, and by Theorem 3.3. We have

$$[\rho_{ij}] - [\delta_{ij}] = [\rho_{ij} \land (1 - \delta_{ij})]$$

$$= [(c_{ij} \lor \delta_{ij}) \land (1 - \delta_{ij})]$$

$$= [(c_{ij} \land (1 - \delta_{ij})) \lor (\delta_{ij} \land (1 - \delta_{ij}))]$$

$$= [c_{ij} \land (1 - \delta_{ij})]$$

$$= [c_{ij}].$$
Shifting the ( ) sign on an operation determines the associative law of the procedure. This condition, analogous to the following theorem.

**Theorem 3.5** Let \( [\rho_y], [\delta_y] \in S^\mu_{\text{mon}} \). Then

i. \( [\rho_y] \cap ([\delta_y] - [\rho_y]) = [0] \).

ii. \( ([\rho_y] \cap [\delta_y]) - [\rho_y] = [0] \).

**Proof.**

i. \( [\rho_y] \cap ([\delta_y] - [\rho_y]) = [\rho_y \cap (\delta_y \cap (1 - \rho_y))] \\
= ([\rho_y \cap (1 - \rho_y)] \cap \delta_y) \\
= [0] \).

ii. \( ([\rho_y] \cap [\delta_y]) - [\rho_y] = (\delta_y \cap (\rho_y \cap (1 - \rho_y))) \\
= [0] \).

The condition of Theorem 3.5, we have \( [\rho_y] \cap ([\delta_y] - [\rho_y]) = ([\rho_y] \cap [\delta_y]) - [\rho_y] \). Furthermore, we will investigate for any \( [\rho_y], [\omega_y], [\delta_y] \in S^\mu_{\text{mon}} \).

**Theorem 3.6** Let \( [\rho_y], [\omega_y], [\delta_y] \in S^\mu_{\text{mon}} \). Then \( [\rho_y] \cap ([\omega_y] - [\delta_y]) = ([\rho_y] \cap [\omega_y]) - [\delta_y] \).

**Proof.**

\( [\rho_y] \cap ([\omega_y] - [\delta_y]) = [\rho_y \cap (\omega_y \cap (1 - \delta_y))] \\
= ([\rho_y \cap \omega_y] \cap (1 - \delta_y)) \\
= ([\rho_y] \cap [\omega_y]) - [\delta_y] \).

Based on the conditions in Theorem 3.1(iii), Theorem 3.5(i), and Theorem 3.6, we present the following theorem.

**Theorem 3.7** Let \( [\rho_y], [\delta_y] \in S^\mu_{\text{mon}} \). Then \( ([\rho_y] - [\delta_y]) \cap ([\delta_y] - [\rho_y]) = [0] \).

**Proof.**

By Theorem 3.6, Theorem 3.5(i), and Theorem 3.1(iii), we have

\( ([\rho_y] - [\delta_y]) \cap ([\delta_y] - [\rho_y]) = ([\rho_y] - [\delta_y]) \cap ([\delta_y] - [\rho_y]) \\
= ([\delta_y] \cap ([\rho_y] - [\delta_y]) - [\rho_y] \\
= [0] - [\rho_y] \\
= [0] \).

Consequences of Theorem 3.7, we get the following theorem.

**Theorem 3.8** Suppose \( [\rho_y], [\delta_y] \in S^\mu_{\text{mon}} \). Then \( ([\rho_y] - [\delta_y]) \cap ([\delta_y] - [\rho_y]) = [0] \).

**Proof.**

From the results of the analysis on the proof of Theorem 3.7, we have

\( ([\rho_y] - [\delta_y]) \cap ([\delta_y] - [\rho_y]) = ([\rho_y] - [\delta_y]) \cap ([\delta_y] - [\rho_y]) = [0] \cap [\rho_y] = [0] \).

In the following, we present the distributive law that applies to intersections against subtractions.

**Theorem 3.9** Let \( [\rho_y], [\omega_y], [\delta_y] \in S^\mu_{\text{mon}} \). Then \( [\rho_y] \cap ([\omega_y] - [\delta_y]) = ([\rho_y] \cap [\omega_y]) - ([\rho_y] \cap [\delta_y]) \).
Proof.
\[
\left[ \rho_y \right] \cap \left[ \left[ c_y \right] - \left[ \delta_y \right] \right] = \left[ \rho_y \wedge \left( c_y \wedge (1 - \delta_y) \right) \right]
\]
\[
= \left[ \left( \rho_y \wedge (1 - \delta_y) \right) \wedge c_y \right]
\]
\[
= \left[ \left( \left( \rho_y \wedge (1 - \rho_y) \right) \vee \left( \rho_y \wedge (1 - \delta_y) \right) \right) \wedge c_y \right]
\]
\[
= \left[ \left( \rho_y \wedge (1 - \rho_y) \right) \vee \left( \rho_y \wedge (1 - \delta_y) \right) \right] \wedge c_y
\]
\[
= \left[ \left( \rho_y \wedge c_y \right) \wedge (1 - \rho_y) \right] \wedge c_y
\]
\[
= \left( \left[ \rho_y \right] \cap [c_y] \right) - \left( \left[ \rho_y \right] \cap [\delta_y] \right).
\]
In Theorem 3.9, distributive law applies to intersections against subtractions. However, it does not apply to such unions that \( \left[ \rho_y \right] \cup \left( \left[ c_y \right] - \left[ \delta_y \right] \right) \neq \left( \left[ \rho_y \right] \cup [c_y] \right) - \left( \left[ \rho_y \right] \cup [\delta_y] \right) \).

As an illustration of this condition, we choose
\[
\left[ \rho_y \right] = \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, \quad \left[ c_y \right] = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 \end{pmatrix}, \quad \left[ \delta_y \right] = \begin{pmatrix} 1 & 1 & 0 & 1 \\ 1 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix} \in S_{104}^M
\]
such that
\[
\left[ \rho_y \right] \cup \left( \left[ c_y \right] - \left[ \delta_y \right] \right) = \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 \end{pmatrix}
\]
and
\[
\left( \left[ \rho_y \right] \cup [c_y] \right) - \left( \left[ \rho_y \right] \cup [\delta_y] \right) = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix}.
\]

Consequences of Theorem 3.6 and 3.9, we get the following theorem.

**Theorem 3.10** Let \( \left[ \rho_y \right] \cdot \left[ c_y \right] \cdot \left[ \delta_y \right] \in S_{104}^M \). Then \( \left( \left[ \rho_y \right] \cap [c_y] \right) - \left( \left[ \rho_y \right] \cup [c_y] \right) = \left( \left[ \rho_y \right] \cap [c_y] \right) - \left( \left[ \rho_y \right] \cup [\delta_y] \right) \).

**Proof.** This is clear with Theorem 3.6 and 3.9. ■

In the following, we present the distributive law that applies to subtractions against intersections and unions.

**Theorem 3.11** Let \( \left[ \rho_y \right] \cdot \left[ c_y \right] \cdot \left[ \delta_y \right] \in S_{104}^M \). Then
\[
\left( \left[ \rho_y \right] \cap [c_y] \right) - \left( \left[ \rho_y \right] \cap [\delta_y] \right) = \left( \left[ \rho_y \right] \cap [c_y] \right) - \left( \left[ \rho_y \right] \cap [\delta_y] \right)
\]
and
\[
\left( \left[ \rho_y \right] \cup [c_y] \right) - \left( \left[ \rho_y \right] \cup [\delta_y] \right) = \left( \left[ \rho_y \right] \cup [c_y] \right) - \left( \left[ \rho_y \right] \cup [\delta_y] \right)
\]

**Proof.**
\[
\left( \left[ \rho_y \right] \cap [c_y] \right) - \left[ \delta_y \right] = \left[ \left( \rho_y \wedge c_y \right) \wedge (1 - \delta_y) \right]
\]
\[
= \left[ \left( \rho_y \wedge (1 - \delta_y) \right) \wedge (c_y \wedge (1 - \delta_y)) \right]
\]
\[
= \left[ \left( \rho_y \wedge (1 - \delta_y) \right) \wedge (c_y \wedge (1 - \delta_y)) \right], \text{ and}
\]
\[
\left( \left[ \rho_y \right] \cup [c_y] \right) - \left[ \delta_y \right] = \left[ \left( \rho_y \vee c_y \wedge (1 - \delta_y) \right]
\]
\[
= \left[ \left( \rho_y \wedge (1 - \delta_y) \right) \wedge (c_y \wedge (1 - \delta_y)) \right]
\]
\[
= \left( \left[ \rho_y \right] \cup [\delta_y] \right) - \left( \left[ \rho_y \right] \cup [\delta_y] \right).
\]
■
With $\land$, $\lor$ and $\neg$ corresponding $\cap$, $\cup$, and $\neg$ respectively, we have De Morgan’s laws for complements.

**Theorem 3.12.** (De Morgan’s Laws) Let $[\rho_y]$, $[c_y]$, and $[\delta_y]$ are the $m \times n$ size soft matrices. Then the following statement is true:

(i). $[\rho_y] - ([c_y] \land [\delta_y]) = ([\rho_y] - [c_y]) \lor ([\rho_y] - [\delta_y])$.

(ii). $[\rho_y] - ([c_y] \lor [\delta_y]) = ([\rho_y] - [c_y]) \land ([\rho_y] - [\delta_y])$.

**Proof.**

(i). $[\rho_y] - ([c_y] \land [\delta_y]) = [\rho_y \land (1 \land (c_y \land \delta_y))]$

$= [\rho_y \land ((1 - c_y) \lor (1 - \delta_y))]$

$= [(\rho_y \land (1 - c_y)) \lor (\rho_y \land (1 - \delta_y))]$

$= ([\rho_y] - [c_y]) \lor ([\rho_y] - [\delta_y])$.

(ii). $[\rho_y] - ([c_y] \lor [\delta_y]) = [\rho_y \land (1 \lor (c_y \lor \delta_y))]$

$= [\rho_y \land ((1 - c_y) \lor (1 - \delta_y))]$

$= [(\rho_y \land (1 - c_y)) \lor (\rho_y \land (1 - \delta_y))]$

$= ([\rho_y] - [c_y]) \land ([\rho_y] - [\delta_y])$. ■

**Consequences of Theorem 3.12,** we get the following theorem.

**Theorem 3.13.** Let $[\rho_y]$, $[\delta_y] \in S_{m,n}$. Then $[\rho_y] - ([c_y] \land [\delta_y]) = [\rho_y] - [\delta_y]$.

**Proof.**

Clear by Theorem 3.12(i). ■

4. **Conclusion**

From the results, the subtraction operation on the soft matrix of size $m \times n$ meets distributive law and De Morgan's law.

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