

Metric on the countable Soft Topological Space

Abstract—The author ATHAR KHARAL defined the Euclidean distance using the symmetric difference of sets in soft space, but not all the sets of ε -approximate elements among the soft sets can compute their symmetric difference in his way. In order to overcome this flaw, in this paper we define the finite(countable) soft topological space, and point out the Euclidean distance given by ATHAR KHARAL can just be applicable to the countable soft space. Meanwhile, authors give the general definition of the metric soft topological space, and test the Euclidean distance being a metric in countable soft topological space, and achieve a metric countable soft topology. **Keywords:** metric, soft topological space, countable soft topology, Euclidean distance, metric soft space.

soft set^{[1][2]} as new mathematical approaches, are widely applied in the uncertainty reasoning, such as computer sciences, economics, medical sciences etc. The references [2]-[15] have shown the flourishing research achievements that have been done in soft set. Topology^[16] which is discussed in such fields by many authors who achieved lots of research results, is one of the greatest unifying ideas of mathematics.

There are influent researches about soft topology, for example: in [17], the authors gave out the concept and idea of soft topology using soft operators, and dealt with its main properties, and found the structure of soft topological spaces. In [18], the researchers put forward the notion of soft topology, and discussed soft T_i -spaces. In [19], the authors gave the properties of soft topological space. In [20]-[27], the authors further studied all kinds of characters of soft topology, such as θ -continuity and connectedness, soft separation axioms, soft connectedness, soft compactness, and so on. However, all the previous research results have not considered the metric soft topology, and in [28], the author defined the Euclidean distance in the soft space, but he did not discuss the metric soft topological space.

This paper will point out the defect of Euclidean distance in the soft space defined by ATHAR KHARAL in [28], and define the finite(countable) soft topology, and further study metric finite(countable) soft topology. It consists of three sections. In section 1, we recall some basic knowledge including concepts and operations of soft sets and topology. In section 2, we discuss the metric on the countable soft topological space, and the conclusion is section 3.

1. Basic knowledge

Definition 1.1.^[1] Let U be an original universe set, E be parameters set. Let $A \subseteq E$, and $\mathcal{P}(U)$ be the power set of U . Then a pair (F, A) is called a **soft set** over U , where mapping F is from A to $\mathcal{P}(U)$.

In other words, the soft set is a parameterized family about the subsets of U . Every set $F(e), \forall e \in E$, from this family may be considered as the set of e -elements of the soft set (F, E) , or considered as the set of e -approximate elements of the soft set.

Inspired by this idea, we can consider a soft set (F, E) as the class of approximations, i.e.

$$(F, E) = \{F(e) \mid e \in E\} = \{(F(e), e) \mid e \in E\}.$$

Definition 1.2.^[1] Let (F_1, B_1) and (F_2, B_2) be the soft sets over a common universe U , and E be an attributes set. $B_1, B_2 \subseteq E, F_i : B \rightarrow \mathcal{P}(U) (i = 1, 2)$ is a set-value mapping over U .

(i) If $B_1 \subseteq B_2$, and $F_1(x) \subseteq F_2(x), \forall x \in B_1 \subseteq B_2$, then the soft sets (F_1, B_1) is a **soft subset** of the soft set (F_2, B_2) , denoted as $(F_1, B_1) \widetilde{\subseteq} (F_2, B_2)$.

(ii) Two soft sets (F_1, B_1) and (F_2, B_2) are said **soft equal**, if $(F_1, B_1) \widetilde{\subseteq} (F_2, B_2)$, and $(F_2, B_2) \widetilde{\subseteq} (F_1, B_1)$. We simply denote by $(F_1, B_1) = (F_2, B_2)$.

(iii) The **union** of (F_1, B_1) and (F_2, B_2) is the soft set (H, C) , where $C = B_1 \cup B_2$, and $\forall e \in C$, denoted as $(F_1, B_1) \widetilde{\cup} (F_2, B_2) = (H, C) = (H, B_1 \cup B_2)$, where

$$H(e) = \begin{cases} F_1(e), & \text{if } e \in B_1 - B_2 \\ F_2(e), & \text{if } e \in B_2 - B_1 \\ F_1(e) \cup F_2(e), & \text{if } e \in B_1 \cap B_2 \end{cases}$$

(iv) The **intersection** of (F_1, B_1) and (F_2, B_2) is the soft set (H, C) is denoted as $(F_1, B_1) \cap (F_2, B_2)$ and is defined as $(F_1, B_1) \cap (F_2, B_2) = (H, C)$, where $C = B_1 \cap B_2$, and $\forall e \in C, H(e) = F_1(e) \cap F_2(e)$.

(v) The **relative complement** of (F, B) is denoted by $(F, B)^c$ and is defined by $(F, B)^c = (F^c, B)$, where $F^c : B \rightarrow \mathcal{P}(U)$, and $F^c(x) = U - F(x), \forall x \in B$.

Obviously, $((F, B)^c)^c = (F, B)$.

(vi) (F, B) is said to be a **relative null soft set**, denoted by $\mathcal{N}$, if $\forall x \in B, F(x) = \emptyset$.

If $B = E$, then it is called **absolute null soft set**, denoted as $\tilde{\emptyset}$.

(vii) (F, B) is a **relative whole soft set** (denoted by $\tilde{U}$), if $\forall x \in B, F(x) = U$.

For convenience to define the definition of distance of soft sets, we give the following soft operators:

Definition 1.3.^[18] Let $\mathcal{T}$ be the collection of soft sets over X , in which X is an initial universe set and E is a set of parameters, then $\mathcal{T}$ is said to be a **soft topology** on X if

(1) $\tilde{\emptyset}, \tilde{X}$ belong to $\mathcal{T}$.

(2) If $\mathcal{T}_1 \subseteq \mathcal{T}$, then $\bigcup_{(F,B) \in \mathcal{T}_1} (F, B) \in \mathcal{T}$, we say the union is closed about any number of soft sets in $\mathcal{T}$.

(3) If $(F, B), (G, C) \in \mathcal{T}$, then $(F, B) \cap (G, C)$ is also in $\mathcal{T}$, that is, the intersection of any two soft sets is closed in $\mathcal{T}$.

The triplet $(X, \mathcal{T}, E)$ is called a **soft topological space** over X .

The members of τ are **soft open sets** in $\mathcal{T}$, the relative complement $(F, B)^c = (F^c, B)$ is said to be a **soft closed set** in $\mathcal{T}$ if $(F, B)^c \in \tau$.

If (F, B) is both soft open and soft closed, then (F, B) is a **soft clopen set**.

Denotation 1. To get the unity of symbols, we can let G be objects set, M be parameters set. B is the subset of M , the mapping $F : B \rightarrow \mathcal{P}(G)$, and (F, B) is the soft set over G , and in the subsequence, (G, τ, M) stands for a soft topological space, and M is a finite attributes set.

2. THE PROPERTIES OF FINITE SOFT METRIC TOPOLOGICAL SPACE

First, we review the definition of metric on the general set.

Definition 2.1. Let X be a set. $\rho : X \times X \rightarrow \mathbb{R}$ is a mapping, if $\forall x, y, z \in X$ having:

- (1) **(positivity)** $\rho(x, y) \geq 0$, and $\rho(x, y) = 0$ if and only if $x = y$;
- (2) **(symmetry)** $\rho(x, y) = \rho(y, x)$;
- (3) **(triangle inequality)** $\rho(x, y) + \rho(y, z) \geq \rho(x, z)$.

Then ρ is called a **metric** over X , (X, ρ) is a **metric space**. and the real number $\rho(x, y)$ is the **distance** from point x to point y .

Next, we define the metric over the soft topology.

Definition 2.2. Let (X, ρ) be a measure space, $x \in X, \forall \varepsilon > 0$.

(1) The set $\{y \in X | \rho(x, y) < \varepsilon\}$ is called a ε -**ball** of x , or ε -**neighborhood** of x ; denoted as $B(x, \varepsilon)$ or B_ε .

(2) Let $A \subseteq X, \forall x \in A, \exists B(x, \varepsilon)$ such that $B(x, \varepsilon) \subset A$, then A is an open set of (X, ρ) .

Definition 2.3. Let (G, τ, M) be a soft topological space, and $\tau = \{(F, B) | (F, B) \text{ is a soft open set over } G\}$ be a soft topology over G .

(1) If $\forall (F, B) \in \tau, \forall e \in B, F(e) \subset G, F(e)$ is a finite subset of G , then τ is called a **finite soft topology**, and (G, τ, M) is called a **finite soft topological space**.

(2) If $\forall (F, B) \in \tau, \forall e \in B, F(e) \subset G, F(e)$ is a countable subset of G , then τ is called a **countable soft topology**, and (G, τ, M) is called a **countable soft topological space**.

Clearly, the finite soft topology is a special case of the countable soft topology.

Remark 2.1. (1) If G is a finite universe set, then τ must be a finite soft topology (defined over G).

(2) Suppose that (G, τ, M) is a soft discrete topological space, if G is a infinite universe set, then τ is a countable infinite soft discrete topology (defined over G); if G is a finite universe set, then τ is a finite soft discrete topology.

Definition 2.4. Let (G, τ, M) be a finite soft topological space, $(F_1, B_1), (F_2, B_2) \in \tau$.

(i) The **difference** between (F_1, B_1) and (F_2, B_2) is the soft set (H, C) , where $C = B_1 \cap B_2$, and $\forall e \in C$, denoted as $(F_1, B_1) - (F_2, B_2) = (H, C) = (H, B_1 \cap B_2)$, where

$$H(e) = F_1(e) \cap F_2^c(e) = F_1(e) \cap (U - F_2(e))$$

(ii) The **symmetric difference** between (F_1, B_1) and (F_2, B_2) is denoted as $(F_1, B_1) \triangle (F_2, B_2)$ and is defined as $((F_1, B_1) \cup (F_2, B_2)) - ((F_1, B_1) \cap (F_2, B_2))$.

Example 2.1. Let (F_1, B_1) and (F_2, B_2) be the soft sets over a common universe $G = \{a, b, c\}$, and $M = \{e_1, e_2, e_3\}$ be an attributes set. $B_1 = \{e_1, e_3\} \subseteq E, B_2 = \{e_1, e_2, e_3\} = E$, and $(F_1, B_1) = \{(e_1, \{a, c\}), (e_3, \{b, c\})\}, (F_2, B_2) = \{(e_1, \{a, c\}), (e_2, \{b\}), (e_3, \{b\})\}$, then $(F_2, B_2)^c = \{(e_1, \{b\}), (e_2, \{a, b\}), (e_3, \{a, c\})\}$; $(F_1, B_1) - (F_2, B_2) = \{(e_1, \emptyset), (e_3, \{c\})\}$; $(F_1, B_1) \cup (F_2, B_2) = \{(e_1, \{a, c\}), (e_2, \{b\}), (e_3, \{b, c\})\}$; $(F_1, B_1) \cap (F_2, B_2) = \{(e_1, \{a, c\}), (e_3, \{b\})\}$; $(F_1, B_1) \triangle (F_2, B_2) = \{(e_1, \emptyset), (e_3, \{c\})\}$.

Definition 2.5. Let (G, τ, M) be a soft topological space in which τ is a finite soft topology. $m : \tau \times \tau \rightarrow G$ is a mapping, $\forall (F_i, B_i) \in \tau, i = 1, 2, 3$ which satisfies the following conditions:

- (1) $m((F_1, B_1), (F_2, B_2)) \geq 0$;
- (2) $m((F_1, B_1), (F_2, B_2)) = m((F_2, B_2), (F_1, B_1))$;
- (3) $m((F_1, B_1), (F_2, B_2)) + m((F_2, B_2), (F_3, B_3)) \geq m((F_1, B_1), (F_3, B_3))$. then m is called the **metric** over (G, τ, M) , and the pair $(\mathcal{T}, m)$ is a **metric soft topological space**, simply speaking, $(\mathcal{T}, m)$ is a **metric soft space**.

In [28], author defined the **Euclidean distance** in the soft space as following:

Definition 2.6. [28] For two soft sets $(F, A), (G, B)$ in a soft space (X, E) , where A and B are not identically void, we define **Euclidean distances**:

$$e((F, A), (G, B)) = \|A \triangle B\| + \sqrt{\sum_{\varepsilon \in A \cap B} \|F(\varepsilon) \triangle G(\varepsilon)\|^2}$$

Normalized Euclidean distances:

$$q((F, A), (G, B)) = \frac{\|A \triangle B\|}{\sqrt{\|A \cup B\|}} + \sqrt{\sum_{\varepsilon \in A \cap B} \chi(\varepsilon)}$$

$$\text{where } \chi(\varepsilon) = \begin{cases} \frac{\|F(\varepsilon) \triangle G(\varepsilon)\|^2}{\|F(\varepsilon) \cup G(\varepsilon)\|}, & \text{if } F(\varepsilon) \cup G(\varepsilon) \neq \emptyset \\ 0, & \text{otherwise} \end{cases}$$

Lemma 2.1. [28] For the soft sets $(F_\emptyset, E), (F_X, E)$ and an arbitrary soft set (F, A) in a soft space, we have:

- (1) $e((F, A), (F, A)^c) = 2\|A\|$;
- (2) $q((F, A), (F, A)^c) = \sqrt{2\|A\|}$;
- (3) $e((F_\emptyset, E), (F_X, E)) = \sqrt{\|E\| \cdot \|X\|}$;
- (4) $q((F_\emptyset, E), (F_X, E)) = \sqrt{\|E\|}$.

Remark 2.2. (1) According to this definition, it is clear that if $(F, A) = (G, B)$, then $e((F, A), (G, B)) = 0$, conversely, if $e((F, A), (G, B)) = 0$ then:

$$\begin{aligned} & e((F, A), (G, B)) = 0 \\ \Rightarrow & \|A \Delta B\| \text{ and } \sum_{\varepsilon \in A \cap B} \|F(\varepsilon) \Delta G(\varepsilon)\|^2 \\ \Rightarrow & A \Delta B = \emptyset \text{ and } F(\varepsilon) \Delta G(\varepsilon) = \emptyset, \forall \varepsilon \in A \cap B \\ \Rightarrow & A \cup B = A \cap B \text{ and } F(\varepsilon) \cup G(\varepsilon) = F(\varepsilon) \cap G(\varepsilon), \\ & \forall \varepsilon \in A \cap B \\ \Rightarrow & A = B \text{ and } F(\varepsilon) = G(\varepsilon), \forall \varepsilon \in A \cap B \\ \Rightarrow & (F, A) = (G, B) \end{aligned}$$

That is, $e((F, A), (G, B)) = 0$ if and only if $(F, A) = (G, B)$.

(2) There is a defect in this definition which makes it only apply to the countable universe, i.e., when $F(\varepsilon)$ and $G(\varepsilon)$ are uncountable sets, it can not be applied to compute $\|F(\varepsilon) \Delta G(\varepsilon)\|$. For example:

Let (G, τ, M) be a soft real topological space in which $G = \mathbb{R}$, $M = \{e_1, e_2, e_3\}$, and $(F_1, B_1), (F_2, B_2)$ are soft set in τ over $\mathbb{R}$.

Suppose that $B_1 = \{e_1, e_2\}$, $B_2 = \{e_1, e_2, e_3\}$, and $(F_1, B_1) = \{(e_1, (1, 3)), (e_2, (1, 4))\}$, $(F_2, B_2) = \{(e_1, (1, 4)), (e_2, (0, 3.5)), (e_3, (2, 4))\}$, then $B_1 \cap B_2 = \{e_1, e_2\}$, from the above definition, we want to compute $e((F_1, B_1), (F_2, B_2))$, then we need to know the cardinality of $F_1(e_1) \Delta F_2(e_2)$, but $F_1(e_1) \Delta F_2(e_1) = [3, 4]$, $F_1(e_2) \Delta F_2(e_2) = (0, 1] \cup [3.5, 4)$, we can not depict its cardinality.

(3) The results given by above Lemma are not correct which should be as follows:

$$\begin{aligned} (1) & e((F, A), (F, A)^c) = \sqrt{\|A\| \cdot \|X\|^2}; \\ (2) & q((F, A), (F, A)^c) = \sqrt{\|A\| \cdot \|X\|}; \\ (3) & e((F_\emptyset, E), (F_X, E)) = \sqrt{\|E\| \cdot \|X\|^2}; \\ (4) & q((F_\emptyset, E), (F_X, E)) = \sqrt{\|E\| \cdot \|X\|}. \end{aligned}$$

In fact, by the definition of soft relative complement, we know

$$\begin{aligned} \text{By } & (F, A)^c = (F^c, A) \\ \Rightarrow & F^c(\varepsilon) = (F(\varepsilon))^c = X - F(\varepsilon), \forall \varepsilon \in A \\ \Rightarrow & F(\varepsilon) \Delta F^c(\varepsilon) = (F(\varepsilon) \cup F^c(\varepsilon)) - (F(\varepsilon) \cap F^c(\varepsilon)) = X \\ \Rightarrow & \|F(\varepsilon) \Delta F^c(\varepsilon)\| = \|A\| \cdot \|X\|^2 \\ \text{and } & \chi(\varepsilon) = \frac{\|F(\varepsilon) \Delta F^c(\varepsilon)\|^2}{\|F(\varepsilon) \cup F^c(\varepsilon)\|} = \frac{\|X\|^2}{\|X\|} = \|X\| \\ \Rightarrow & e((F, A), (F, A)^c) = \sqrt{\|A\| \cdot \|X\|^2} \\ \Rightarrow & q((F, A), (F, A)^c) = \sqrt{\|A\| \cdot \|X\|} \end{aligned}$$

$$\text{And } F_\emptyset(\varepsilon) \Delta F_X(\varepsilon) = \emptyset \Delta X = X$$

$$\begin{aligned} \text{and } & \chi(\varepsilon) = \frac{\|F_\emptyset(\varepsilon) \Delta F_X(\varepsilon)\|^2}{\|F_\emptyset(\varepsilon) \cup F_X(\varepsilon)\|} = \frac{\|X\|^2}{\|X\|} = \|X\| \\ \Rightarrow & e((F_\emptyset, E), (F_X, E)) = \sqrt{\|E\| \cdot \|X\|^2} \\ \Rightarrow & q((F_\emptyset, E), (F_X, E)) = \sqrt{\|E\| \cdot \|X\|}. \end{aligned}$$

based on the remark, we should modify the above definition as follows:

Definition 2.7. Let (G, τ, M) be a finite soft topological space, for arbitrary soft sets $(F_1, B_1), (F_2, B_2) \in \tau$, where $B_1, B_2 \subseteq M$, B_1 and B_2 are not identically void, the

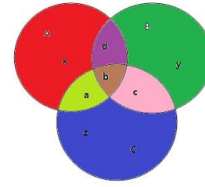


Fig. 1

mappings $e, q : \tau \times \tau \rightarrow \mathbb{R}^+$ we denote **Euclidean distance** between (F_1, B_1) and (F_2, B_2) as $e((F_1, B_1), (F_2, B_2))$, and define as :

$$e((F_1, B_1), (F_2, B_2)) = \|B_1 \Delta B_2\| + \sqrt{\sum_{\varepsilon \in B_1 \cap B_2} \|F_1(\varepsilon) \Delta F_2(\varepsilon)\|^2}$$

and we denote **Normalized Euclidean distance** between (F_1, B_1) and (F_2, B_2) as $q((F_1, B_1), (F_2, B_2))$, and define as:

$$\begin{aligned} q((F_1, B_1), (F_2, B_2)) &= \frac{\|B_1 \Delta B_2\|}{\sqrt{\|B_1 \cup B_2\|}} + \sqrt{\sum_{\varepsilon \in B_1 \cap B_2} \chi(\varepsilon)} \\ \text{where } \chi(\varepsilon) &= \begin{cases} \frac{\|F_1(\varepsilon) \Delta F_2(\varepsilon)\|^2}{\|F_1(\varepsilon) \cup F_2(\varepsilon)\|}, & \text{if } F_1(\varepsilon) \cup F_2(\varepsilon) \neq \emptyset \\ 0, & \text{otherwise} \end{cases} \end{aligned}$$

Lemma 2.2. Let A, B, C be any set, then

$$\begin{aligned} (1) & \|A \Delta B\| = \|B \Delta A\|; \\ (1) & \|A \Delta C\| \leq \|A \Delta B\| + \|B \Delta C\|. \end{aligned}$$

Proof: (1) It is clear because

$$A \Delta B = A \cup B - A \cap B = B \cup A - B \cap A = B \Delta A.$$

(2) We prove (2) using Venn Diagram. From Fig.1, we can see $\|A \Delta B\| = x + a + y + c$, $\|B \Delta C\| = y + d + z + a$, $\|A \Delta C\| = x + d + z + c$, and

$$\begin{aligned} \|A \Delta C\| &= x + d + z + c \\ &= (x + z) + (d + c) \\ &\leq (x + 2y + z) + (2a + d + c) \\ &= \|A \Delta B\| + \|B \Delta C\| \end{aligned}$$

Proposition 2.1. Let (G, τ, M) be a countable soft topological space, for arbitrary soft sets $(F_1, B_1), (F_2, B_2) \in \tau$, where A and B are not identically void, the Euclidean distance $e((F_1, B_1), (F_2, B_2))$ between soft set (F_1, B_1) and (F_2, B_2) defined as above definition, then the mapping $e : \tau \times \tau \rightarrow \mathbb{R}^+$ is a metric.

Proof: Using definition of Euclidean distance, Remark 2.2 and Lemma 2.2, it is obvious. ■

Definition 2.8. Let $\mathcal{T} = (G, \tau, M)$ be a countable soft topological space, the mapping $e : \tau \times \tau \rightarrow \mathbb{R}^+$ be a metric determined by Euclidean distance over $\mathcal{T}$, then τ is **induced by the metric** e , simply speaking, τ is a **measurable**

countable soft topology, and the pair $(\mathcal{T}, e)$ is called as a **metric countable soft topological space**.

For any soft topological (G, τ, M) , we also hope there is a metric such that (G, τ, M) can be a measurable soft topological space, for example:

Example 2.2. Let (G, τ, M) be the soft topological space, $\forall (F_1, B_1), (F_2, B_2) \in \tau$, define

$$d((F_1, B_1), (F_2, B_2)) = \begin{cases} 1, & \text{if } (F_1, B_1) \neq (F_2, B_2) \\ 0, & \text{otherwise} \end{cases}$$

then $\tau = \{(F, B) | (F, B) \text{ is a soft open set over } G\}$ is a soft discrete topology induced by d .

The example above shows that a definite metric induces a soft topology, but this metric is very special. So far we have not found a proper metric which can induce a metric soft topology in a random soft topological space, and we will discuss it later.

3. CONCLUSION

our aim is to discuss the metric on the countable soft topological space, we hope to offer a new idea for data classification.

This paper discusses metric on the countable soft topological space. Three points are mainly covered: Firstly, we point the Euclidean distance defined on the soft space by ATHAR KAHRAL which there is a defect, and we modify it. Secondly, we define the finite and countable soft topology, define the metric countable soft topology. Lastly, we point out the limitation of Euclidean distance which can not apply to infinite universe and propose the next work.

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