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MATRIX REPRESENTATION OF FINITE SOFT TOPOLOGIES

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ABSTRACT

In this paper, matrix representation of a finite soft topology is discussed. Muhammad Shabir and MunazzaNaz have shown that every soft topology gives a parametrized family of topologies on a set X. However they have an example to show that the converse is not true. The converse is discussed hereand it is established that every finite soft topology with finite parameter space is represented by a matrix whose elements are sets and each row represents a finite topology on X and conversely every such matrix represents a finite soft topology.

Keywords: *Soft sets, Soft Topology, Soft open, Soft closed, Parametrized family.*

1. INTRODUCTION

Probability theory, Fuzzy sets [22], intuitionistic fuzzy sets [3], interval mathematics [7] and rough sets [15] deal with uncertainties, but they have their own limitations due to the inadequacy of the parameterization of these theories.To overcome these difficulties Molodtsov [12] initiated the notion of soft sets associated with parameters in the year 1999. Soft set theory is free from the difficulties and soft sets have applications to data reduction [23], data mining [18, 20], medical image processing [17], parameter reduction [6, 21]. In the soft set theory we can use any convenient parameterization strategy. The problem of setting the membership function does not arise in soft set theory, which makes soft set theory very convenient and practicable. Following this, Maji *et.al.* [10, 11] defined several operations on soft set theory and he described an application of soft set theory to decision making problems [9]. Muhammad Shabir introduced the concept of soft topology [13]. Following this several Mathematicians concentrated their studies on applications of soft topology [9]. Both topology and soft topology have application to image processing [17]. The purpose of this paper is to discuss thematrix representation of a finite soft topology.

2. PRELIMINARIES

Let X be an initial universe and E be a set of parameters. A pair (F, E) is called a soft set [4] over X, where $F : E \to 2^X$ is a mapping. S(X, E) denotes the collection of all soft sets over X with parameter space E. We denote (F, E) by $\tilde{F}$. Moreover we can denote $\tilde{F}$ by $\tilde{F}$ = {(e, F(e)): e$\in$E}. Soft set theoretic operations are discussed in [10]. Let $\tilde{F}$ and $\tilde{G}$ be any two soft sets over a common universe X with a common parameter space E. $\tilde{F}$ is a soft subset of $\tilde{G}$ if $F(e) \tilde{\subseteq} G(e)$ for all $e \in E$. If $\tilde{F}$ is a soft subset of $\tilde{G}$ then we write $\tilde{F} \tilde{\subseteq} \tilde{G}$. Also $\tilde{F} = \tilde{G}$ if and only if $F(e) = G(e)$ for all $e \in E$.

A soft set $\tilde{\phi}$ over X is said to be a NULL soft set if for all $e \in E$, $\phi(e) = \phi$ (empty set). A soft set $\tilde{X}$ over X is said to be an absolute soft set if for all e$\in$E, $X(e) = X$.

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The union of two soft sets $\tilde{F}$ and $\tilde{G}$ over X is defined as $\tilde{F}\,\tilde{\cup}\,\tilde{G}=(F\,\tilde{\cup}\,G,E)$ where $(F\,\tilde{\cup}\,G)(e)=F(e)\cup G(e)$ for all $e\in E$.The intersection of two soft sets $\tilde{F}$ and $\tilde{G}$ over X is defined as $\tilde{F}\,\tilde{\cap}\,\tilde{G}=(F\,\tilde{\cap}\,G,E)$ where $(F\,\tilde{\cap}\,G)(e)=F(e)\cap G(e)$ for all $e\in E$. The arbitrary union and arbitrary intersection of soft sets $(F_\alpha: E)$, $\alpha\in\Delta$ are defined as $\tilde{\cup}\{\widetilde{F_\alpha:\alpha\in\Delta}\}=(\tilde{\cup}\{F_\alpha:\alpha\in\Delta\},E)$ and $\tilde{\cap}\{\widetilde{F_\alpha:\alpha\in\Delta}\}=(\tilde{\cap}\{F_\alpha:\alpha\in\Delta\},E)$
where $(\tilde{\cup}\{F_\alpha:\alpha\in\Delta\})(e)=\cup\{F_\alpha(e):\alpha\in\Delta\}$ and $(\tilde{\cap}\{\widetilde{F_\alpha}:\alpha\in\Delta\})(e)=\cap\{F_\alpha(e):\alpha\in\Delta\}$, for all $e\in E$.

The complement of a soft set $\tilde{F}$ is denoted by $(\tilde{F})'=(F',E)$ where $F': E\to 2^X$ is a mapping given by $F'(e)=X-F(e)$ for all $e\in E$..

Let $\tilde{F}$ be a soft set over X and $x\in X$, Then $x\in\tilde{F}$ if $x\in F(e)$ for all $e\in E$.

Definition 2.1: Let X be an initial universal set. If $\tilde{\tau}$ is a collection of soft sets over X, then $\tilde{\tau}$ is said to be a soft topology [10] on X if

(1) $\tilde{\phi}$, $\tilde{X}$ belong to $\tilde{\tau}$

(2) Arbitrary union of soft sets in $\tilde{\tau}$ belongs to $\tilde{\tau}$,

(3) The intersection of any two soft sets in $\tilde{\tau}$ belongs to $\tilde{\tau}$.

If $\tilde{\tau}$ is a soft topology over X then$(X,\tilde{\tau},E)$ is a soft space over X.

Lemma 2.2[13]: Let $(X,\tilde{\tau},E)$ be a soft space over X. Then the collection $(\tilde{\tau})_e=\{\tilde{F}(e):\tilde{F}\in\tilde{\tau}\}$ defines a topology on X, for each $e\in E$.

In the next section, PFT($\tilde{\tau}$) denotes the parameterized family of topologies on X induced by $\tilde{\tau}$. That is PFT($\tilde{\tau}$) = $\{(\tilde{\tau})_e: e\in E\}$.|PFT($\tilde{\tau}$)| denotes the cardinality of PFT($\tilde{\tau}$).

3. PARAMETRIZED FAMILY OF TOPOLOGIES INDUCED BY A SOFT TOPOLOGY

Proposition 3.1: Let $\tilde{\tau}$ be a soft topology over X with parameter space E. Then |PFT($\tilde{\tau}$)|$\le|E|$ and $|(\tilde{\tau})_e|\le|\tilde{\tau}|$ for every $e\in E$.

Proof: Define $\varphi: E\to$ PFT($\tilde{\tau}$) by $\varphi(e)=(\tilde{\tau})_e$. Clearly φ is onto. Therefore |PFT($\tilde{\tau}$)|$\le|E|$. Now define $\theta:\tilde{\tau}\to(\tilde{\tau})_e$ by $\theta(\tilde{F})=\tilde{F}(e)$. Obviously θ is onto. Therefore $|(\tilde{\tau})_e|\le|\tilde{\tau}|$.

It is note worthy to see that there is a soft topological space $(X,\tilde{\tau},E)$ for which $|(\tilde{\tau})_e|<|\tilde{\tau}|$ and |PFT($\tilde{\tau}$)|= |E| as shown in the next example.

Example 3.2: Let X= $\{a_1, a_2, a_3\}$ E=$\{e_1,e_2\}$ and $\tilde{\tau}=\{\tilde{\phi},\tilde{X},\tilde{F}_1,\tilde{F}_2,\tilde{F}_3,\tilde{F}_4,\tilde{F}_5,\tilde{F}_6,\tilde{F}_7,\tilde{F}_8,\tilde{F}_9\}$
where

$\tilde{F}_1=\{(e_1\{a_2\}),(e_2\{a_1\})\}$
$\tilde{F}_2=\{(e_1,\{a_2,a_3\}),(e_2,\{a_1,a_2\})\}$ $\tilde{F}_3=\{(e_1,\{a_1,a_2\}),(e_2,\{a_1,a_2\})\}$
$\tilde{F}_4=\{(e_1\{a_1,a_2\})\},(e_2,\{a_1,a_3\})\}$ $\tilde{F}_5=\{e_1,\{\tilde{X}\}),(e_2,\{a_1,a_2\})\}$
$\tilde{F}_6=\{(e_1,\{a_2\})\},(e_2\{a_1,a_2\})\}$ $\tilde{F}_7=\{(e_1,\{a_2,a_3\})\},(e_2\{\tilde{X}\})\}$,
$\tilde{F}_8=\{(e_1,\{a_1,a_2\}),(e_2,\{\tilde{X}\})\}$, $\tilde{F}_9=\{(e_1,a_2),(e_2,\{\tilde{X}\})\}$

Then $\tilde{\tau}$ defines a soft topology on X and hence $(X,\tilde{\tau},E)$ is a soft topological space over X. It can be easily seen that $(\tilde{\tau})_{e_1}=\{\{\phi,X\},\{a_2\},\{a_1,a_2\},\{a_2,a_3\}\}$
and $(\tilde{\tau})_{e_2}=\{\phi,X,\{a_1\},\{a_1,a_3\},\{a_2,a_3\}\}$ are topologies on X.

Here $(\tilde{\tau})_{e_1} \neq (\tilde{\tau})_{e_2}$. PFT ($\tilde{\tau}$) = { $(\tilde{\tau})_{e_1}$, $(\tilde{\tau})_{e_2}$ }.|PFT($\tilde{\tau}$)|=2 and $|E|$ = 2

This shows that PFT($\tilde{\tau}$) =2 = $|E|$ and $|(\tilde{\tau})_{e_1}|$=5<11=$|\tilde{\tau}|$.

The next example shows that |PFT($\tilde{\tau}$)|< |E| for some soft topological space (X, $\tilde{\tau}$,E) .

Example 3.3: Let X= {b_1, b_2, b_3}, E={k_1,k_2} and $\tilde{\tau}$ = { $\tilde{\phi}$, $\tilde{X}$, $\tilde{G}_1, \tilde{G}_2, \tilde{G}_3, \tilde{G}_4, \tilde{G}_5, \tilde{G}_6$}

where $\tilde{G}_1$ = {(k_1,{ b_2}), (k_2,{ b_2}) }, $\tilde{G}_2$ ={(k_1,{X}), (k_2,{b_2 ,b_3 }) },

$\tilde{G}_3$ ={ (k_1,{ b_2}), (k_2,{ X }) }, $\tilde{G}_4$ = {(k_1,{ b_2}), (k_2,{ b_2,b_3}) }

$\tilde{G}_5$ ={(k_1,{ b_2, b_3}), (k_2,{ X})} $\tilde{G}_6$ ={(k_1,{b_2, b_3}), (k_2,{ b_2, b_3}) }

Then $\tilde{\tau}$ defines a soft topology on X and hence (X, $\tilde{\tau}$, E) is a soft topological space over X. It can be easily seen that $(\tilde{\tau})_{k_1}$ = { ϕ, X, {b_2}, {b_2 , b_3} } and $(\tilde{\tau})_{k_2}$ ={ ϕ, X, {b_2}, {b_2 , b_3}} are topologies on X.

Here $(\tilde{\tau})_{k_1} = (\tilde{\tau})_{k_2}$ and |PFT($\tilde{\tau}$)| =1 and |E| = 2

This proves |PFT($\tilde{\tau}$)| < |E|.
It is interesting to see that there is a soft topology for which
$|(\tilde{\tau})_e| = |\tilde{\tau}|$

Example 3.4: Let X= {d_1, d_2, d_3}, E = { β_1, β_2 } and $\tilde{\tau}$ = { $\tilde{\phi}$, $\tilde{X}$, $\tilde{L}_1, \tilde{L}_2$ }
where $\tilde{L}_1$ = {(β_1 ,{ d_2,d_3}), (β_2 ,{d_2,d_3})} $\tilde{L}_2$ ={(β_1 ,{d_2}), (β_2 ,{d_2})}
Then $\tilde{\tau}$ defines a soft topology on X and hence (X, $\tilde{\tau}$, E) is a soft topological space over X. For every parameter of E. It can be easily seen that

{ $\left(\tilde{\tau}\right)_{\beta_1}$ ={ϕ, X, {d_2}, {d_2, d_3}} and $(\tilde{\tau})_{\beta_2}$ ={ ϕ, X, {d_2},{ d_2,d_3}} are topologies on X.

Here $(\tilde{\tau})_{\beta_1} = (\tilde{\tau})_{\beta_2}$.$|(\tilde{\tau})_e|$ = 4 and $|\tilde{\tau}|$ = 4. Hence $|(\tilde{\tau})_e|$ = $|\tilde{\tau}|$ and |PFT($\tilde{\tau}$)| =1< 2=|E|.

4. MATRIX REPRESENTATION OFA SOFT TOPOLOGY

Muhammad Shabir *et al.* established that every soft topology induces a parameterized family of topological spaces and further gave an example to that show that the converse is not true. (Computers and Mathematics with Applications 61(2011) 1786-1799).Then the following question will arise.

Given a collection { $\tau_e : e \in E$ } of topologies on X, does there exist a soft topology $\tilde{\tau}$ over X with parameter space E such that $(\tilde{\tau})_e = \tau_e$, for all $e \in E$. This question is discussed in this section.

Let (X, $\tilde{\tau}$, E) be a soft topological space with finite parameter space E = {e_1,e_2,….,e_n}. According to Shabir, $\tilde{\tau}$ induces a parameterized collection of topologies $(\tilde{\tau})_e, e \in E$. That is for each e_i, let $(\tilde{\tau})_{e_i} = \{G_{i1}, G_{i2}, \ldots. G_{in}\}$ be the topology over X, for each $e_i \in$E. Let

$$\text{Mat}(\tilde{\tau}) = \begin{bmatrix} (\tilde{\tau})_{e_1} \\ (\tilde{\tau})_{e_2} \\ \vdots \\ (\tilde{\tau})_{e_n} \end{bmatrix} \ldots\ldots\ldots.. \quad (*)$$

$$= \begin{bmatrix} G_{11} & G_{12} & G_{13} & \cdots & G_{1n} \\ G_{21} & G_{22} & G_{23} & \cdots & G_{2n} \\ G_{31} & G_{32} & G_{33} & \cdots & G_{3n} \\ \cdots & \cdots & \cdots & \cdots & \vdots \\ \cdots & \cdots & \cdots & \cdots & \vdots \\ G_{n1} & G_{n2} & G_{n3} & \cdots & G_{nn} \end{bmatrix} \text{ where } G_{i1} = \phi \text{ and } G_{in} = X .$$

Therefore every soft topology $\tilde{\tau}$ over X can be identified by a matrix of the form (*)

Remark 4.1: The soft topologies in Example 3.3, Example 3.4 and Example 3.5 can be represented in the matrix forms.

Example 3.3: $\text{Mat}(\tilde{\tau}) = \begin{bmatrix} (\tilde{\tau})_{e_1} \\ (\tilde{\tau})_{e_2} \end{bmatrix} = \begin{bmatrix} \phi & \{a_2\} & \{a_1, a_2\} & \{a_2, a_3\} & X \\ \phi & \{a_1\} & \{a_1, a_3\} & \{a_2, a_3\} & X \end{bmatrix}.$

Example 3.4: $\text{Mat}(\tilde{\tau}) = \begin{bmatrix} (\tilde{\tau})_{k_1} \\ (\tilde{\tau})_{k_2} \end{bmatrix} = \begin{bmatrix} \phi & \{b_2\} & \{b_2, b_3\} & X \\ \phi & \{b_2\} & \{b_2, b_3\} & X \end{bmatrix}.$

Example 3.5: $\text{Mat}(\tilde{\tau}) = \begin{bmatrix} (\tilde{\tau})_{\beta_1} \\ (\tilde{\tau})_{\beta_2} \end{bmatrix} = \begin{bmatrix} \phi & \{d_2\} & \{d_2, d_3\} & X \\ \phi & \{d_2\} & \{d_2, d_3\} & X \end{bmatrix}.$

Theorem 4.2: Let E=$\{e_1, e_2, e_3, ..., e_n\}$ be a finite parametric space.

$$\text{Let } M = \begin{bmatrix} G_{11} & G_{12} & G_{13} & \cdots & G_{1n} \\ G_{21} & G_{22} & G_{23} & \cdots & G_{2n} \\ G_{31} & G_{32} & G_{33} & \cdots & G_{3n} \\ \cdots & \cdots & \cdots & \cdots & \vdots \\ \cdots & \cdots & \cdots & \cdots & \vdots \\ G_{n1} & G_{n2} & G_{n3} & \cdots & G_{nn} \end{bmatrix} \text{ where } G_{i1} = \phi \text{ and } G_{in} = X \text{ such that}$$

1) i^{th} row represents a topology τ_{e_i} on X,
2) For each j, k there exists l such that $G_{ij} \cup G_{ik} = G_{il}$ for all i
3) For each j, k there exists r such that $G_{ij} \cap G_{ik} = G_{ir}$ for all i.

Then there is a soft topology $\tilde{\tau}$ over X with the parameter space E such that M = Mat($\tilde{\tau}$)

Proof: Define $\tilde{F}_j$: E $\rightarrow 2^X$ by $\tilde{F}_j(e_i) = G_{ij}$ for i=1,2,3, ….,n. Then $\{ \tilde{F}_j : j = 1, 2, ..., n \}$ is a collection of soft sets over X with parameter space E.

Claim : $\tilde{\tau} = \{\tilde{F}_1, \tilde{F}_2, ..., \tilde{F}_n\}$ is a soft topology on X

$\tilde{F}_1(e_i) = G_{i1} = \phi$ that implies $\tilde{\phi} = \tilde{F}_1 \in \tilde{\tau}$

$\tilde{F}_n(e_i) = G_{in} = X$ so that $\tilde{X} = \tilde{F}_n \in \tilde{\tau}$

$\left(\widetilde{F_j} \cup \widetilde{F_k}\right)(e_i) = F_j\left(e_i\right) \cup F_k\left(e_i\right) = G_{ij} \cup G_{ik} = G_{il} = \tilde{F}_l\left(e_i\right)$. That is $\tilde{F}_j \cup \tilde{F}_k = \tilde{F}_l \in \tilde{\tau}$.

$\left(\widetilde{F_j} \cap \widetilde{F_k}\right)(e_i) = F_j\left(e_i\right) \cap F_k\left(e_i\right) = G_{ij} \cap G_{ik} = G_{ir} = \tilde{F}_r\left(e_i\right)$

i.e. $\tilde{F}_j \cap \tilde{F}_k = \tilde{F}_r \in \tilde{\tau}$

Then $\tilde{\tau}$ is a soft topology over X with a parameter space E.

Claim: $(\tilde{\tau})_{e_i} = \tau_{e_i}$ for i= 1, 2,..., n

$(\tilde{\tau})_{e_i}$ = $\{ \tilde{F}_j(e_i) : \tilde{F}_j \in \tilde{\tau} \}$ = $\{ G_{ij}$: j = 1, 2,...,n$\}$ = $(\tilde{\tau})_{e_i}$ for i= 1,2,...,n

$$\therefore \text{Mat}(\tilde{\tau}) = \begin{bmatrix} (\tilde{\tau})_{e_1} \\ (\tilde{\tau})_{e_2} \\ \vdots \\ (\tilde{\tau})_{e_n} \end{bmatrix} = \begin{bmatrix} \tau_{e_1} \\ \tau_{e_2} \\ \vdots \\ \tau_{e_n} \end{bmatrix} = \begin{bmatrix} G_{11} & G_{12} & G_{13} & \cdots & G_{1n} \\ G_{21} & G_{22} & G_{23} & \cdots & G_{2n} \\ G_{31} & G_{32} & G_{33} & \cdots & G_{3n} \\ \cdots & \cdots & \cdots & \cdots & \vdots \\ \cdots & \cdots & \cdots & \cdots & \vdots \\ G_{n1} & G_{n2} & G_{n3} & \cdots & G_{nn} \end{bmatrix} = \text{M}$$

The above theorem is justified in the following example.

Example 4.3: Let X = {a, b, c}, E = {e_1, e_2, e_3} and

τ_{e_1} = { ϕ ,{a}, {a, b}, X} τ_{e_2} ={ ϕ ,{b}, {b, c}, X} τ_{e_3} ={ ϕ , {c}, {a, c}, X}

Then matrix representation of the above family of topologies is

$$\text{M} = \begin{bmatrix} \tau_{e_1} \\ \tau_{e_2} \\ \tau_{e_3} \end{bmatrix} = \begin{bmatrix} \phi & \{a\} & \{a,b\} & X \\ \phi & \{b\} & \{b,c\} & X \\ \phi & \{c\} & \{a,c\} & X \end{bmatrix} = \begin{bmatrix} G_{11} & G_{12} & G_{13} & G_{14} \\ G_{21} & G_{22} & G_{23} & G_{24} \\ G_{31} & G_{32} & G_{33} & G_{34} \end{bmatrix}$$

It is easy to verify the conditions 1, 2, and 3 of the above theorem. It can be easily verified.

Each column represents a soft set over X. The first column represents $\tilde{\phi}$, Second column represents $\tilde{F}_1$, Third column represents $\tilde{F}_2$ and Fourth column represents $\tilde{X}$ where

$\tilde{F}_1$ (e_1) = {a}, $\tilde{F}_1$ (e_2) = {b} and $\tilde{F}_1$ (e_3) = {c}

$\tilde{F}_2$ (e_1) = {a, b}, $\tilde{F}_2$ (e_2) = {b, c} and $\tilde{F}_2$ (e_3) = {a, c}

$\tilde{F}_3$ (e_1) = {a, b}, $\tilde{F}_3$ (e_2) = {b} and $\tilde{F}_3$ (e_3) = {c}

$\tilde{F}_4$ (e_1) = {a}, $\tilde{F}_4$ (e_2) = {b, c} and $\tilde{F}_4$ (e_3) = {c} and

$\tilde{F}_5$ (e_1) = {a, b}, $\tilde{F}_5$ (e_2) = {b, c} and $\tilde{F}_5$ (e_3) = {c}

Therefore $\tilde{F}_1$ = {(e_1, {a}), (e_2, {b}), (e_3, {c})}, $\tilde{F}_2$ = {(e_1, {a, b}), (e_2, {b, c}), (e_3, {a, c})},

$\tilde{F}_3$={(e_1,{a, b}), (e_2,{ b}), (e_3,{c})}, $\tilde{F}_4$ ={(e_1,{a}), (e_2,{ b, c}), (e_3,{c})}, and

$\tilde{F}_5$ = {(e_1, {a, b}), (e_2, {b, c}), (e_3,{c})}

Then $\tilde{\tau}$ = { $\tilde{F}_1, \tilde{F}_2, \tilde{F}_3, \tilde{F}_4, \tilde{F}_5$} is a soft topology over X with a parameter space E.

Here $(\tilde{\tau})_{e_1}$ ={ ϕ ,{a}, {a, b}, X} = τ_{e_1} $(\tilde{\tau})_{e_2}$ ={ ϕ ,{b}, {b, c}, X}= τ_{e_2} and $(\tilde{\tau})_{e_3}$ ={ ϕ , {c}, {a, c}, X}= τ_{e_3}

$$\text{Therefore Mat}(\tilde{\tau}) = \begin{bmatrix} \tau_{e_1} \\ \tau_{e_2} \\ \tau_{e_3} \end{bmatrix} = \begin{bmatrix} \phi & \{a\} & \{a,b\} & X \\ \phi & \{b\} & \{b,c\} & X \\ \phi & \{c\} & \{a,c\} & X \end{bmatrix} = \begin{bmatrix} G_{11} & G_{12} & G_{13} & G_{14} \\ G_{21} & G_{22} & G_{23} & G_{24} \\ G_{31} & G_{32} & G_{33} & G_{34} \end{bmatrix} = \text{M}$$

Thus the theorem is justified by this example.

5. CONCLUSION

Soft topology is characterized using matrix under suitable conditions. Every finite family of topologies induces a soft topology with finite parameter space.

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