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On soft Γ-semigroups

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Abstract. Let U be an initial universe and E a set of parameters. A pair (F, A) is called a soft set over U if $F : E \to P(U)$ where $P(U)$ denotes the power set of U and $A \subseteq E$. In this paper, we introduce the concept of soft Γ-semigroups and soft (left, right) ideals using soft sets and investigate some properties.

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1. Introduction

In 1999, the notion of soft sets was introduced as an effective mathematical tool to deal with uncertainly by Molodtsov (see [6]). In 2003, Maji, Biswas and Roy defined binary operations on soft sets (see [5]). However, these binary operations was corrected by Ali, Feng, Lui, Min and Shabir in [3]. There are relations between soft sets and algebraic structures. In [1, 2, 4], the authors applied soft sets to semirings, rings and groups, respectively. In [8], the authors defined soft semigroups and soft ideals over a semigroup. Recently, Shabir and Ahmad introduced the concept of soft ternary semigroups as a collection of ternary subsemigroup of a ternary semigroup and defined soft (left, right, lateral, quasi, bi) ideals of a ternary semigroup (see [7]).

In [9], Sen and Saha defined a Γ-semigroup as a generalization of a semigroup. The purpose of this paper is to introduce soft Γ-semigroups, soft (left, right) ideals and investigate some properties.

Let us recall some definitions concerning Γ-semigroups. Let S and Γ be two nonempty sets. Then S is called a Γ-*semigroup* if there exists a mapping $S \times \Gamma \times S \to S$, written as $(x, \gamma, y) \mapsto x\gamma y$, such that $(x\gamma y)\beta z = x\gamma(y\beta z)$ for all $x, y, z \in S$ and all $\gamma, \beta \in \Gamma$. For nonempty subsets A and B of S, let

$$A\Gamma B = \{a\gamma b \mid a \in A, b \in B, \gamma \in \Gamma\}.$$

For $x \in S$, let $A\Gamma x = A\Gamma\{x\}$ and $x\Gamma A = \{x\}\Gamma A$. A nonempty subset T of S is called a Γ-*subsemigroup* of S if for all $x, y \in T$ and $\gamma \in \Gamma$, $x\gamma y \in T$. S is said to be *commutative* if for all $x, y \in S$ and $\gamma \in \Gamma$, $x\gamma y = y\gamma x$.

Let S be a Γ-semigroup. A nonempty subset A of S is called a *left (right) ideal* of S if $S\Gamma A \subseteq A$ ($A\Gamma S \subseteq A$). If A is both left and right ideal of S, then A is called an *ideal* of S. An ideal A of S is said to be *idempotent* if $A\Gamma A = A$.

Hereafter, let S be a Γ-semigroup.

2. Preliminaries

Let U be an *initial universe* and E a set of *parameters*. A pair (F, A) is called a *soft set* over U if

$$F : E \to P(U)$$

where $P(U)$ denotes the power set of U and $A \subseteq E$. For two soft sets (F, A) and (G, B) over a common universe U, we say that (F, A) is a *subset* of (G, B), denoted by $(F, A) \subseteq (G, B)$, if

(i) $A \subseteq B$,
(ii) $F(a) \subseteq G(a)$ for all $a \in A$.

We say that (F, A) and (G, B) are *equal* if $(F, A) \subseteq (G, B)$ and $(G, B) \subseteq (F, A)$.

The following are operations defined between soft sets.

Definition 2.1. Let (F, A) and (G, B) be soft sets over a common universe U. Let "$(F, A)OR(G, B)$" be a soft set over U, denoted by $(F, A) \vee (G, B)$, defined by $(F, A) \vee (G, B) = (K, A \times B)$ where

$$K(a, b) = F(a) \cup G(b)$$

for all $(a, b) \in A \times B$.

Definition 2.2. Let (F, A) and (G, B) be soft sets over a common universe U. Let "$(F, A)AND(G, B)$" be a soft set over U, denoted by $(F, A) \wedge (G, B)$, defined by $(F, A) \wedge (G, B) = (H, A \times B)$ where

$$H(a, b) = F(a) \cap G(b)$$

for all $(a, b) \in A \times B$.

Definition 2.3. Let (F, A) and (G, B) be soft sets over a common universe U.

(1) The *extension union* of (F, A) and (G, B), denoted by $(F, A) \cup_E (G, B)$, is the soft set (H, C) where $C = A \cup B$ and for $e \in C$,

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

(2) The *restricted union* of (F, A) and (G, B), denoted by $(F, A) \cup_R (G, B)$, is the soft set (H, C) where $C = A \cap B$ and for $e \in C$, $H(e) = F(e) \cup G(e)$.

(3) The *extension intersection* of (F, A) and (G, B), denoted by $(F, A) \cap_E (G, B)$, is the soft set (H, C) where $C = A \cup B$ and for $e \in C$,

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

(4) The *restricted intersection* of (F, A) and (G, B), denoted by $(F, A) \cap_R (G, B)$, is the soft set (H, C) where $C = A \cap B$ and for $e \in C$, $H(e) = F(e) \cap G(e)$.

Hereafter, we shall consider a soft set over S, a Γ-semigroup.

3. Main results

Definition 3.1. The Γ-*restricted product* of soft sets (F, A) and (G, B) over S, denoted by $(F, A)\overline{\Gamma}(G, B)$, is defined as a soft set

$$(K, D) = (F, A)\overline{\Gamma}(G, B)$$

where $D = A \cap B \neq \varnothing$ and $K : D \to P(S)$ such that

$$K(d) = F(d)\Gamma G(d)$$

for all $d \in D$.

Definition 3.2. A soft set (F, A) over S is called a *soft* Γ-*semigroup* over S if $(F, A)\overline{\Gamma}(F, A) \subseteq (F, A)$.

Example 3.3. Let $M = \{-i, 0, i\}$ and $\Gamma = A = \{-i, i\}$. We have M is a Γ-semigroup. Define $F : A \to P(M)$ by $F(i) = F(-i) = A$. Then (F, A) is a soft Γ-semigroup over M.

Example 3.4. Let M and Γ be the set of all 3×3 diagonal matrices over the set of positive integers. Then M is a Γ-semigroup under the usual matrix multiplication. Let $\mathbb{N}$ be the set of all positive integers. Define $F : \mathbb{N} \to P(M)$ by $F(n) = \{A \in M : \det(A) \geq n\}$. We obtain $(F, \mathbb{N})$ is a soft Γ-semigroup over M.

Example 3.5. For $n \in \mathbb{N}$ such that $n \geq 4$, we consider

$$\mathbb{Z}_{2n} = \{[0], [1], [2], \ldots, [2n-1]\} \text{ and } \Gamma = \{[0], [n]\}.$$

It is easy to see that $\mathbb{Z}_{2n}$ is a Γ-semigroup. Take $A = \{[4a] : 0 \leq a \leq n\}$ and $B = \{[2b] : 0 \leq b \leq n\}$. Define $F : A \to P(\mathbb{Z}_{2n})$ by $F([x]) = \{[0], [2x]\}$ and defined $G : B \to P(\mathbb{Z}_{2n})$ by $G([x]) = \{[0], [2x], [4x]\}$. We have

$$F([a])\Gamma F([a]) = \{[0]\} \subseteq F([a]) \text{ and } G([b])\Gamma G([b]) = \{[0]\} \subseteq G([b])$$

for all $[a] \in A, [b] \in B$. Hence (F, A) and (G, B) are soft Γ-semigroups over $\mathbb{Z}_{2n}$.

Theorem 3.6. *A soft set (F, A) over S is a soft Γ-semigroup over S if and only if for all $a \in A$ such that $F(a) \neq \varnothing$, $F(a)$ is a Γ-subsemigroup of S.*

Proof. Assume that a soft set (F, A) over S is a soft Γ-semigroup over S. Let $a \in A$ be such that $F(a) \neq \varnothing$. We have

$$(F, A)\overline{\Gamma}(F, A) = (K, A \cap A) \text{ and } K(a) = F(a)\Gamma F(a)$$

for all $a \in A$. Since $K \subseteq F$, $K(a) \subseteq F(a)$. So, $F(a)\Gamma F(a) \subseteq F(a)$. Thus $F(a)$ is a Γ-subsemigroup of S.

Conversely, assume that $F(a)$ is a Γ-subsemigroup of S for all $a \in A$ such that $F(a) \neq \varnothing$. We have

$$(F, A)\overline{\Gamma}(F, A) = (K, A \cap A) \text{ and } K(a) = F(a)\Gamma F(a)$$

for all $a \in A$. By assumption, $K(a) \subseteq F(a)$. Thus $(K, A) \subseteq (F, A)$. Therefore, a soft set (F, A) over S is a soft Γ-semigroup over S. $\square$

Let (S, E) be the soft set over S defined by $S(e) = S$ for all $e \in S$. This is called an *absolute soft set* over S.

Definition 3.7. A soft set (F, A) over S is called a *soft l-idealistic (r-idealistic)* over S if $(S, E)\overline{\Gamma}(F, A) \subseteq (F, A)$ $((F, A)\overline{\Gamma}(S, E) \subseteq (F, A))$.

Example 3.8. We consider $\mathbb{Z}_8 = \{[0], [1], [2], [3], [4], [5], [6], [7]\}$. Let $\Gamma = \{[1], [4]\}$, then $\mathbb{Z}_8$ is a Γ-semigroup. Take $C = \{[0], [4]\}$. Define $H : C \to P(\mathbb{Z}_8)$ by $H(c) = C$ for all $c \in C$. Then (H, C) is a soft l-idealistic over $\mathbb{Z}_8$.

Theorem 3.9. *A soft set (F, A) over S is a soft l-idealistic (r-idealistic) over S if and only if for all $a \in A$ such that $F(a) \neq \varnothing$, $F(a)$ is a left (right) ideal of S.*

Proof. Assume that a soft set (F, A) over S is a soft l-idealistic over S. Let $a \in A$ be such that $F(a) \neq \varnothing$. We have

$$(S, E)\overline{\Gamma}(F, A) = (K, E \cap A) \text{ and } K(a) = S(a)\Gamma F(a)$$

for all $a \in A$. Since $K \subseteq F$, $K(a) \subseteq F(a)$. Since $S\Gamma F(a) = S(a)\Gamma F(a) \subseteq F(a)$, $F(a)$ is a left ideal of S.

Conversely, assume that $F(a)$ is a left ideal of S for all $a \in A$ such that $F(a) \neq \varnothing$. We have

$$(S, E)\overline{\Gamma}(F, A) = (K, E \cap A) \text{ and } K(a) = S(a)\Gamma F(a)$$

for all $a \in A$. By assumption, $K(a) = S(a)\Gamma F(a) = S\Gamma F(a) \subseteq F(a)$. Thus $(K, A) \subseteq (F, A)$. Therefore, a soft set (F, A) over S is a soft l-idealistic over S.

That a soft set (F, A) over S is a soft r-idealistic over S if and only if for all $a \in A$ such that $F(a) \neq \varnothing$, $F(a)$ is a right ideal of S can be proved similarly. $\square$

Proposition 3.10. *Let (F, A) and (G, B) be soft Γ-semigroups over S. If $A \cap B \neq \varnothing$, then $(F, A) \cap_R (G, B)$ is a soft Γ-semigroup over S.*

Proof. Assume that $A \cap B \neq \varnothing$. Let $(H, C) = (F, A) \cap_R (G, B)$ where $C = A \cap B \neq \varnothing$ and $H(c) = F(c) \cap G(c)$ for all $c \in C$. To show that (H, C) is a soft Γ-semigroup over S, we have to show that $(H, C)\overline{\Gamma}(H, C) \subseteq (H, C)$. Let $(K, D) = (H, C)\overline{\Gamma}(H, C)$ where $D = C \cap C$ and $K(d) = H(d)\Gamma H(d)$ for all $d \in D$. For $d \in D$, we have

$$K(d) = H(d)\Gamma H(d) = (F(d) \cap G(d))\Gamma(F(d) \cap G(d)) \subseteq F(d) \cap G(d) = H(d)$$

Then $K \subseteq H$. Therefore, $(F, A) \cap_R (G, B)$ is a soft Γ-semigroup over S. $\square$

Proposition 3.11. *Let (F, A) and (G, B) be soft Γ-semigroups over S. If $A \cap B \neq \varnothing$, then $(F, A) \cup_E (G, B)$ is a soft Γ-semigroup over S.*

Proof. Assume that $A \cap B \neq \varnothing$. Let $(H, C) = (F, A) \cup_E (G, B)$ where

$$H(c) = \begin{cases} F(c) & \text{if } c \in A \setminus B, \\ G(c) & \text{if } c \in B \setminus A, \\ F(c) \cap G(c) & \text{if } c \in A \cap B. \end{cases}$$

To show that (H,C) is a soft Γ-semigroup over S, we have to show that

$$(H,C)\overline{\Gamma}(H,C) \subseteq (H,C).$$

Let $(K,D) = (H,C)\overline{\Gamma}(H,C)$ where $D = C \cap C$ and $K(d) = H(d)\Gamma H(d)$ for all $d \in D$. For $d \in D$, we have

$$K(d) = H(d)\Gamma H(d) \subseteq \begin{cases} F(d) & \text{if } d \in A \setminus B, \\ G(d) & \text{if } d \in B \setminus A, \\ F(d) \cap G(d) & \text{if } d \in A \cap B. \end{cases}$$

Then $K(d) \subseteq H(d)$. Therefore, $(F,A) \cup_E (G,B)$ is a soft Γ-semigroup over S. □

Proposition 3.12. *Let (F,A) and (G,B) be soft Γ-semigroups over S. Then $(F,A) \wedge (G,B)$ is a soft Γ-semigroup over S.*

Proof. Let $(F,A) \wedge (G,B) = (H, A \times B)$ where $H(a,b) = F(a) \cap G(b)$ for all $(a,b) \in A \times B$. To show that $(H, A \times B)$ is a soft Γ-semigroup over S, let $(K,D) = (H, A \times B)\overline{\Gamma}(H, A \times B)$ where $D = (A \times B) \cap (A \times B)$ and $K(a,b) = H(a,b)\Gamma H(a,b)$ for all $(a,b) \in D$. For $(a,b) \in D$, we have

$$K(a,b) = H(a,b)\Gamma H(a,b) = (F(a) \cap G(b))\Gamma(F(a) \cap G(b)) \subseteq F(a) \cap G(b) = H(a,b)$$

Then $K \subseteq H$. Therefore, $(F,A) \wedge (G,B)$ is a soft Γ-semigroup over S. □

Definition 3.13. Let (F,A) and (G,B) be soft sets over a Γ-semigroup S. Define $(F,A)\Gamma^*(G,B)$ is a soft set $(K, A \times B)$ where $K(a,b) = F(a)\Gamma G(b)$.

Proposition 3.14. *Let (F,A) and (G,B) be soft Γ-semigroups over S. If S is commutative, then $(F,A)\Gamma^*(G,B)$ is a soft Γ-semigroup over S.*

Proof. Let $(F,A)\Gamma^*(G,B) = (H, A \times B)$ where $H(a,b) = F(a)\Gamma G(b)$ for all $(a,b) \in A \times B$. To show that $(H, A \times B)$ is a soft Γ-semigroup over S, let

$$(K,D) = (H, A \times B)\overline{\Gamma}(H, A \times B)$$

where $D = (A \times B) \cap (A \times B)$ and $K(a,b) = H(a,b)\Gamma H(a,b)$ for all $(a,b) \in D$. For $(a,b) \in D$, since S is commutative, we have

$$K(a,b) = H(a,b)\Gamma H(a,b) = (F(a)\Gamma G(b))\Gamma(F(a)\Gamma G(b)) \subseteq F(a)\Gamma G(b) = H(a,b)$$

Then $K \subseteq H$. Therefore, $(F,A)\Gamma^*(G,B)$ is a soft Γ-semigroup over S. □

Proposition 3.15. *If (F,A) and (G,B) are soft l-idealistics (r-idealistics) over S, then $(F,A) \cap_R (G,B)$ is a soft l-idealistic (r-idealistic) over S contained in both (F,A) and (G,B).*

Proof. Assume that (F,A) and (G,B) are soft l-idealistic over S. Let $(H,C) = (F,A) \cap_R (G,B)$ where $C = A \cap B \neq \varnothing$ and $H(c) = F(c) \cap G(c)$ for all $c \in C$. To show that (H,C) is a soft l-idealistic over S, we have to show that $(S,E)\overline{\Gamma}(H,C) \subseteq (H,C)$. Let $(K,D) = (S,E)\overline{\Gamma}(H,C)$ where $D = S \cap C$ and $K(d) = S(d)\Gamma H(d)$ for all $d \in D$. For $d \in D$, we have

$$K(d) = S(d)\Gamma H(d) = S(d)\Gamma(F(d) \cap G(d)) \subseteq F(d) \cap G(d) = H(d)$$

Then $K \subseteq H$. Therefore, $(F, A) \cap_R (G, B)$ is a soft l-idealistic over S. Similarly, if (F, A) and (G, B) are soft r-idealistics over S, then $(F, A) \cap_R (G, B)$ is a soft r-idealistic over S. It is clear by definition that $(F, A) \cap_R (G, B)$ is contained in both (F, A) and (G, B). □

Proposition 3.16. *If (F, A) and (G, B) are soft l-idealistics (r-idealistics) over S, then $(F, A) \cup_E (G, B)$ is a soft l-idealistic (r-idealistic) over S containing both (F, A) and (G, B).*

Proof. Straightforward. □

Proposition 3.17. *If (F, A) and (G, B) are soft l-idealistics (r-idealistics) over S, then $(F, A) \vee (G, B)$ is a soft l-idealistic (r-idealistic) over S.*

Proof. Straightforward. □

Proposition 3.18. *If (F, A) and (G, B) are soft l-idealistics (r-idealistics) over S, then $(F, A) \wedge (G, B)$ is a soft l-idealistic (r-idealistic) over S containing both (F, A) and (G, B).*

Proof. Straightforward. □

Definition 3.19. Let (F, A) and (G, B) be soft sets over S such that $(G, B) \subseteq (F, A)$. Then (G, B) is called a *soft Γ-subsemigroup* of (F, A) if $G(b)$ is a Γ-subsemigroup of $F(b)$ for all $b \in B$.

Definition 3.20. Let (F, A) and (G, B) be soft sets over S such that $(G, B) \subseteq (F, A)$. Then (G, B) is called a *soft ideal* of (F, A) if $G(b)$ is an ideal of $F(b)$ for all $b \in B$.

Example 3.21. Let $M = [0, 1]$ and $\Gamma = \{\frac{1}{n} : n \in \mathbb{N}\}$. For $n \in \mathbb{N}$, let $A_n = [0, \frac{1}{n}]$ and $B_n = [0, \frac{1}{2n}]$. We define $F_n : A_n \to P(M)$ by $F_n(x) = [0, x]$ for all $x \in A_n$ and $G_n : B_n \to P(M)$ by $G_n(y) = [0, \frac{y}{2}]$ for all $y \in B_n$. For $m, n \in \mathbb{N}$ such that $m \leq n$ the following hold.

(1) (F_n, A_n) and (G_n, B_n) are soft Γ-semigroups over M.
(2) (G_n, B_n) is a soft Γ-subsemigroup of (F_m, A_m).
(3) (G_n, B_n) is a soft ideal of (F_m, A_m).
(4) (F_n, A_n) and (G_n, B_n) are soft l-idealistics over M.

Example 3.22. We have $\mathbb{Z}_8 = \{[0], [1], [2], [3], [4], [5], [6], [7]\}$ is a Γ-semigroup where $\Gamma = \{[1], [4]\}$. Let $A = \{[0], [1], [2], [4]\}$ and $B = \{[0], [1], [4]\}$. Defined $F : A \to P(\mathbb{Z}_8)$ by $F(a) = A$ for all $a \in A$ and $G : B \to P(\mathbb{Z}_8)$ by $G(b) = B$ for all $b \in B$. Then (F, A) and (G, B) are soft Γ-semigroups over $\mathbb{Z}_8$. Moreover, (G, B) is a soft Γ-subsemigroup of (F, A). However, (G, B) is not a soft ideal of (F, A) because $[2] = [1][1][2] \in G([1])\Gamma F([1])$ and $[2] \notin B = G([1]), G([1])\Gamma F([1]) \nsubseteq G([1])$.

Theorem 3.23. *Let (F, A) be a soft Γ-semigroup over S. Let $\{(H_i, B_i) \mid i \in I\}$ be a nonempty family of soft Γ-subsetmigroups of (F, A).*

(1) *$\bigcap_R (H_i, B_i)$ is a soft Γ-subsetmigroup of (F, A).*
(2) *$\wedge_{i \in I}(H_i, B_i)$ is a soft Γ-subsetmigroup of $\wedge_{i \in I}(F, A)$.*
(3) *$\bigcup_E (H_i, B_i)$ is a soft Γ-subsetmigroup of (F, A) if B_i, $i \in I\}$, are pair wise disjoint.*

Proof. Straightforward. □

Theorem 3.24. *Let (F, A) be a soft Γ-semigroup over S. Let $\{(H_i, B_i) \mid i \in I\}$ be a nonempty family of soft ideals of (F, A).*

(1) $\bigcap_R (H_i, B_i)$ *is a soft ideal of* (F, A).
(2) $\wedge_{i\in I}(H_i, B_i)$ *is a soft ideal of* $\wedge_{i\in I}(F, A)$.
(3) $\bigcup_E (H_i, B_i)$ *is a soft ideal of* (F, A).
(4) $\vee_{i\in I}(H_i, B_i)$ *is a soft ideal of* $\vee_{i\in I}(F, A)$.

Proof. Straightforward. □

Theorem 3.25. *If (G, B) is a soft ideal of (F, A), then (G, B) is a soft Γ-subsemigroup of (F, A).*

Proof. Let (G, B) be a soft ideal of (F, A). Then for all $b \in B$ we have $G(b) \subseteq F(b)$ and $G(b)$ is an ideal of $F(b)$. Hence for all $b \in B$ we obtain $G(b)\Gamma G(b) \subseteq G(b)\Gamma F(b) \subseteq F(b)$. Thus (G, B) is a soft Γ-subsemigroup of (F, A). □

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