

Review Article

Historical Development on Soft Set Theory

R. Karpagam, V. S. Selvi

Department of Mathematics, Theivanai Ammal College for Women (Autonomous)
Villupuram, 605 602, Tamil Nadu, India.

Corresponding author e-mail: karpagam12dgl@gmail.com

Abstract

Molodtsov originated the idea of soft sets, some research on soft sets has been done in the literature. The concept of soft set is fundamentally important in almost every scientific field. Soft set theory is a new mathematical tool for dealing with uncertainties and is a set associated with parameters and has been applied in several directions. In particular, the work demonstrates that soft set theory can be applied to problems that contain uncertainties especially in decision making problems. These applications explain the voluminous work in this field within a short period of time. We emphasize that soft set has enough developed basic supporting structures through which various algebraic structures in theoretical point of view could be developed. We define the notion of soft sets, and the study that are interesting and valuable in the theory of soft sets, which emphasis on a series of applications especially in decision making problems. In this paper, studying the concept of soft set theory, types of soft set development and review its existing literature.

Keywords: BCI-algebra; BCK-Algebra; FCM - Fuzzy cognitive map; Fuzzy Set; Fuzzy Soft Set; Soft Rough Set; Soft Semi Rings; Soft Set; Uncertainty.

Introduction

Most of our real life problems in engineering, social and medical science, economics, environment etc. involve imprecise data and their solutions involve the use of mathematical principles based on uncertainty and imprecision. To handle such uncertainties, a number of theories have been proposed. Some of these are probability, fuzzy sets, intuitionistic fuzzy sets, interval mathematics and rough sets etc. All these theories, however, are associated with an inherent limitation, which is the inadequacy of the parameterization tool associated with these theories. Some inherent problems of probability theory and interval mathematics can be found in soft set theory. Molodtsov initiated the novel concept of soft set as a new mathematical tool for dealing with uncertainties. A completely new approach was proposed for modelling vagueness and uncertainty in soft set theory [1].

Soft set theory is free from the difficulties where as other existing methods viz. Probability Theory, Fuzzy Set Theory [2,3], Intuitionistic fuzzy set theory [4], Rough Set Theory [5] etc. which can be considered as mathematical tools

for dealing with uncertainties, have their own difficulties. Probability theory is applicable only for stochastically stable system. Interval mathematics is not sufficiently adaptable for problems with different uncertainties. Setting the membership function value is always been a problem in fuzzy set theory. Moreover all these techniques lack in the parameterization of the tools and they could not be applied successfully in tackling problems. It is further pointed out that the reason for these difficulties is, possibly, the inadequacy of the parameterization tool of the theory.

There is no limited condition to the description of objects; Many of the established paradigms appear as special cases of Soft Set Theory, so researchers can choose the form of parameters they need, which greatly simplifies the decision making process and make the process more efficient in the absence of partial information. [6] studied the theory of soft sets initiated by Molodstov, they defined equality of two soft sets, subset and super set of a soft set, complement of a soft set, null soft set and absolute soft set with examples. Soft binary operations like AND, OR and also the operations of union, intersection were also defined.

[7] improved the work of [6]. Some new notions such as the restricted intersection, the restricted union, the restricted difference and the extended intersection of two soft sets along with a new notion of complement of a soft set [8]. Similarity measures have extensive application in pattern recognition, region extraction, coding theory, image processing and in many other areas. Presently, work on the soft set theory is making progress rapidly. In the standard soft set theory, a situation may be complex in the real world because of the fuzzy nature of the parameters. With this point of view [9], expanded this theory to fuzzy soft set theory and discussed some immediate outcomes. To continue the investigation on fuzzy soft sets, [10] introduced the notion of a mapping on the classes of fuzzy soft sets which is a pivotal notion for the advanced development of any new area of mathematical sciences. Similarity of two fuzzy soft sets has been studied by [11] and application of similarity between generalized fuzzy soft sets has been studied by them in [12,13]. The algebraic structure of soft set theory has been studied increasingly in recent years.

Definition and Preliminaries

In this section, we recall some basic notion of soft set theory introduced by [1] and some useful definition from [6]. Here, U to be an initial universal set and E to be a set of parameters and $A, B \subset E$ [14].

Definition (Soft Set) 1

Let U be an initial universe set and E be a set of parameters. Let $P(U)$ denote the power set of U and $A \subset E$. A pair (F, A) is called a soft set over U , where F is a mapping given $F : A \rightarrow P(U)$. In other words, a soft set over U is a parameterized family of subsets of the universe U . For $\varepsilon \in A$, $F(\varepsilon)$ may be considered as the set of approximate elements of the soft set (F, A) [15].

Examples 1.1

A soft set (F, A) describes the attractiveness of the houses which Mr. X is going to buy.

U = the set of houses under consideration.

A = the set of parameters. Each parameter is a word or a sentence.

$A = \{\text{expensive; beautiful; wooden; cheap; in the green surroundings; modern; in good repair; in bad repair}\}$.

In this case, to define a soft set means to point out expensive houses, beautiful houses, and so on. It is worth noting that the sets $F(\varepsilon)$ may be empty for some $\varepsilon \in A$.

Definition (Operation with Soft set) 2

Suppose a binary operation denoted by $*$, is defined for all subsets of the set U . Let (F, A) and (G, B) be two soft sets over U . Then the operation $*$ for the soft sets is defined in the following way: $(F, A) * (G, B) = (H, A \times B)$ Where $H(\alpha, \beta) = (\alpha) * (\beta)$, $\alpha \in A$, $\beta \in B$ and $A \times B$ is the Cartesian product of the sets A and B .

Definition (NOT Set of a Set of Parameters) 3

Let $E = e_1, e_2, e_3 \dots e_n$ be a set of parameters. The NOT set of E denoted by $\neg E$ defined by $\neg E = \{\neg e_1, \neg e_2, \neg e_3 \dots \neg e_n\}$ where $\neg e_i = \text{not } e_i$ for all i . It may be noted that \neg and \lrcorner are two different operations.

Definition (Complement of a Soft Set) 4

The complement of a soft set (F, A) is denoted by $(F, A)^c$ and is defined by $(F, A)^c = (F^c, \lrcorner A)$ where $F^c : \lrcorner A \rightarrow P(U)$ is a mapping which is defined by $F^c(\alpha) = U - F(\lrcorner \alpha)$, for all $\alpha \in \lrcorner A$.

Definition (Relative complement of a soft set) 5

The relative complement of a soft set (F, A) is denoted by $(F, A)^r$ and is defined by $(F, A)^r = (F^r, A)$ where $F^r : A \rightarrow P(U)$ is a mapping given by $F^r(\alpha) = U - F(\alpha)$, for all $\alpha \in A$.

Definition (NULL Soft Set) 6

A soft set (F, A) over U is said to be a NULL soft set denoted by Φ , if for all $\varepsilon \in A$, $F(\varepsilon) = \emptyset$ (null-set).

Definition (Relative NULL Soft Set) 7

A soft set (F, A) over U is said to be relative NULL soft set with respect to parameter set A denoted by Φ , if for all $\varepsilon \in A$, $F(\varepsilon) = \emptyset$ (null-set).

Definition (Relative Whole Soft Set) 8

A soft set (F, A) over U is said to be relative whole soft set (with respect to parameter set A) denoted by UA , if for all $\varepsilon \in A$, $F(\varepsilon) = U$.

Definition (Absolute Soft Set) 9

The relative whole soft set (E) with respect to the universe set of parameters E is called the absolute soft set over U .

Definition (AND Operation on Two Soft Sets) 10

If (F, A) and (G, B) be two soft sets then (F, A) AND (G, B) denoted by $(F, A) \wedge (G, B)$ and is defined by $(F, A) \wedge (G, B) = (H, A \times B)$ where $H(\alpha, \beta) = F(\alpha) \cap G(\beta)$ for all $(\alpha, \beta) \in A \times B$.

Definition (OR Operation on Two Soft Sets) 11

If (F, A) and (G, B) be two soft sets then (F, A) OR (G, B) denoted by $(F, A) \vee (G, B)$ is defined by $(F, A) \vee (G, B) = (O, A \times B)$ where $O(\alpha, \beta) = F(\alpha) \cup G(\beta)$ for all $(\alpha, \beta) \in A \times B$ [16].

Historical Perspective

Fuzzy set theory, which was firstly proposed by researcher Zadeh in 1965, has become a very important tool to solve problems and provides an appropriate framework for representing vague concepts by allowing partial membership. The origin of soft set theory could be traced to the work of [5] in 1993 titled Hard sets and soft sets [17]. His notion of soft sets is a unified view of classical, rough and fuzzy sets. This motivated by Molodtsov in 1999 titled soft set theory: first result, there in, the basic notions of the theory of soft sets and some of its possible applications were presented.

A set theory for soft computing and presenting unified view of fuzzy sets via neighbourhoods [18]. This paper proposed fuzzy sets should be abstractly defined by such structures and are termed soft sets (sofsets). Based on such structures, W-sofset, F-sofset, P-sofset, B-sofset, C-sofset, N-sofset, FP-sofset, and FF-sofsets have been identified. [19] presented a combination of fuzzy and soft set theories; fuzzy soft set theory is a more general soft set model which makes descriptions of the objective world more general, realistic, practical and accurate in some cases of decision making. In 2003 again presented soft set theory with some implementation in their work. [15] presented a novel method of object recognition from an imprecise multi observer data in decision making problem. [7] have discussed the relationship between soft sets and information

systems. It is showed that soft sets are a class of special information systems. After soft sets are extended to several classes of general cases, the more general results also show that partition - type soft sets and information systems have the same formal structures, and that fuzzy soft sets and fuzzy information systems are equivalent. [20], in his paper, an appropriate definition and method is designed for recognizing soft information patterns by establishing the information table based on soft sets theory and at the same time the solutions are proposed corresponding to the different recognition vectors.

In [21] studied the texture classification via Soft Set Theory based in a Classification Algorithm. In [22] have introduces the basic properties of soft sets and compare soft sets to the related concepts of fuzzy sets and rough sets. In the same year, [23] have presented the stability of sets given by constraints is considered within the context of the theory of soft sets. The study of soft set [24] extended to soft semirings. The notions of soft semirings, soft sub-semirings, soft ideals, idealistic soft semirings and soft semi ring homomorphism were introduced, and several related properties were investigated. A new algebra method is Soft BCK/BCI-algebras and apply the notion of soft sets by Molodtsov to commutative ideals of BCK-algebras [25], commutative soft ideals and commutative idealistic soft BCK-algebras are introduced, and their basic properties are investigated. Heuristic algorithm has presented a of normal parameter reduction [26].

Furthermore, the normal parameter reduction is also investigated in fuzzy soft sets. [27] presented the definition of soft modules and construct some basic properties using modules. [28] presented the concept of soft fuzzy set and its properties. [29] in this paper data analysis approach of soft sets under incomplete information is calculated by weighted-average of all possible choice values of the object, and the weight of each possible choice value is decided by the distribution of other objects. In [8] gives some new notions such as the restricted intersection, the restricted union, the restricted difference and the extended intersection of two soft sets. [30] proposed an approach for visualizing soft maximal association rules which contains four main steps, including discovering,

visualizing maximal supported sets, capturing and finally visualizing the maximal rules under soft set theory. [31] applied the notion of soft sets to the theory of BCK/BCI- algebras and introduced soft sub algebras and then derived their basic properties with some illustrative examples. [32] introduced the concept of soft Hilbert algebra, soft Hilbert abysmal algebra and soft Hilbert deductive algebra and investigated their properties. [33] introduced the combination of interval-valued fuzzy set and soft set models. The complement, AND, OR operations, DeMorgan's, associative and distribution laws of the interval-valued fuzzy soft sets are then proved. [34] introduce the basic notions of soft rings, which are actually a parameterized family of sub-rings of a ring, over a ring[35], presented the concept of soft set relations are introduced as a sub soft set of the Cartesian product of the soft sets and many related concepts such equivalent soft set relation, partition, composition, function etc. [36] define soft matrices and their operations which are more functional to make theoretical studies in the soft set theory and finally construct a soft max-min decision making method which can be successfully applied to the problems that contain uncertainties and also improving several new results, products of soft sets and uni-int decision function [37]. [38] aim of this paper is providing a framework to combine fuzzy sets, rough sets, and soft sets all together, which gives rise to several interesting new concepts such as rough soft sets, soft rough sets, and soft-rough fuzzy sets. [39,40] aimed to give deeper insights into decision making involving interval valued fuzzy soft sets, a hybrid model combining soft with interval valued fuzzy sets. Many authors works in different areas like Soft lattices [41], bijective soft set [42], on soft mappings[13]. [12] have further generalised the concept of fuzzy soft sets as introduced by [6]. [43], paper deals with the algebraic structure of soft sets and constructed lattice structures. It is proved that soft equality is a congruence relation with respect to some operations and the soft quotient algebra is established.[44], in his paper proposes the notion of exclusive disjunctive soft sets and studies some of its operations, such as, restricted/relaxed AND operations, dependency between exclusive disjunctive soft sets and bijective soft sets etc. [45] introduce the notion of vague soft set which is an extension to the soft set and discuss basic properties of vague soft

sets. [46] studied some important properties associated with these new operations. A collection of all soft sets with respect to new operations give rise to four idempotent monoids.[47], in his paper, as a generalization of Molodtsov's soft set introduce the definitions of a soft multi set, its basic operations such as complement, union and intersection. [48] introduces soft subfields of a field and soft submodule of a left R-module their related properties about soft substructures of rings, fields and modules are investigated. In this paper [49], Anti-symmetric relation and transitive closure of a soft set relation are introduced and proposed Warshall's algorithm. [50] have introduced the notion of soft ring and soft ideal over a ring and some examples are given.

Also obtain some new properties of soft rings and soft ideals. [51,52], presented to establish an interesting connection between two mathematical approaches to vagueness: rough sets and soft sets. Also define new types of soft sets such as full soft sets, intersection complete soft sets and partition soft sets. [53] paper based on some results of soft operations, using the DeMolan's laws and gives the distributive laws of the restricted union and the restricted intersection and the distributive laws of the union and the extended intersection. [54] paper investigated operational rules given by [6] and [8,46] and obtains some sufficient necessary conditions such that corresponding operational rules hold and give correct forms for some operational rules. [55] defined fuzzy soft ring and study some of its algebraic properties. [56], a soft set approach for association rule mining have define the notion of regular and maximal association rules between two sets of parameters. [57] extended fuzzy soft sets with fuzzy DLs, i.e., present an extended fuzzy soft set theory by using the concepts of fuzzy DLs to act as the parameters of fuzzy soft sets and define some operations for the extended fuzzy soft sets. [58] present the notions of positive implicative soft ideals and positive implicative idealistic soft BCK-algebras are introduced, and their basic properties are derived. [10] defined the notion of a mapping on soft classes and studied several properties of images and inverse images of soft sets supported by examples. [59] introduced implicative soft ideals in BCK-algebras and implicative idealistic soft BCK- algebras and related properties are investigated. [60]

presented soft-rings and idealistic soft rings. [14] defined soft matrices based on soft set and operations of soft matrices are defined like AND, OR, union, intersection etc. for soft matrices are investigated. [61] discussed basic properties of operations on soft sets such as intersection, extended intersection, restricted union and restricted difference and illustrated their interconnections between each other. Same author also introduce Soft groups and normalistic soft group [62]. In [63] the notions of anti-reflexive kernel, symmetric kernel, reflexive closure, and symmetric closure of a soft set relation are first introduced, respectively. Finally, soft set relation mappings and inverse soft set relation mappings are proposed. [64] applied the concept of intuitionistic fuzzy soft sets to semi-group theory.

In [65] defined concept of a soft lattice, soft sub-lattice, complete soft lattice, modular soft lattice, distributive soft lattice, soft chain and study their related properties. [66] have studied the concept of similarity between soft sets, which is an extension of the equality for soft set theory. [67] presented the main objective and clarify some conceptual misunderstandings of the fundamentals of soft set theory and investigate some distributive and absorption properties of operations on soft sets [68]. [69], in this paper established some new results related to distributive properties of AND (\wedge) and OR (\vee) operations with respect to operations of union, restricted union restricted intersection, extended intersection and restricted difference on soft sets.[70], this paper aims to extend classical soft sets to trapezoidal fuzzy soft sets based on trapezoidal fuzzy numbers. [71], an integrated FCM and fuzzy soft set for supplier selection problem based on risk evaluation. This study first integrates the Fuzzy Cognitive Map (FCM) and fuzzy soft set model for solving the supplier selection problem. [72], presented the innovative definition like the operations of union, intersection, OR and AND operators of soft intuitionistic fuzzy sets along with illustrative examples. [73], to discuss the idea of reduction of parameters in case of soft sets and studied approximation space of Pawlak associated with a soft set. [74] studied the equivalence soft set relations and obtain soft analogues of many results concerning ordinary equivalence relations and partitions. [75] introduce several notions, such as soft topological soft groups, soft

topological soft normal subgroups, and soft topological soft factor groups, and to study their properties. [76] applied the concept of intuitionistic fuzzy soft sets to rings. The concept of intuitionistic fuzzy soft rings is introduced and some basic properties of intuitionistic fuzzy soft rings has given. Intersection, union, AND, and OR operations of intuitionistic fuzzy soft rings are defined.

Further [77] introduced a new notion of soft element of a soft set and establish its natural relation with soft operations and soft objects in soft topological spaces. Next, using the notion of soft element, they define, in a different way than in the literature, a soft mapping transforming a soft set into a soft set and provide basic properties of such mappings. The new approach to soft mappings enables us to obtain the natural first fixed point results in the soft set theory. [78] introduces order of the soft groups, power of the soft sets, power of the soft groups, and cyclic soft group on a group. They also investigate the relationship between cyclic soft groups and classical groups. In China [79] initiate the study of soft congruence relations by using the soft set theory. The notions of soft quotient rings, generalized soft ideals and generalized soft quotient rings, are introduced, and several related properties are investigated.

Also, they obtain a one-to-one correspondence between soft congruence relations and idealistic soft rings and a one-to-one correspondence between soft congruence relations and soft ideals. In particular, the first, second, and third soft isomorphism theorems are established, respectively. In International Journal of Fuzzy Mathematics and Systems [80] introduces soft pre T_1 space in the soft topological spaces. The notations of soft pre interior and soft pre closure are generalized using these sets. [81] the Cartesian products on fuzzy soft set are defined, and the fuzzy soft relations can be presented based on the Cartesian products, including uni-int decision relation and level fuzzy soft relation. [82] the practical application of interval-valued intuitionistic fuzzy soft multi sets in real-world decision making problems and proposed an algorithm to solve multi weighted interval valued intuitionistic fuzzy soft multi set based decision making by applying weighted choice values. [83] studied the hesitant fuzzy soft sets and some

operations on hesitant fuzzy soft sets are defined and some of their properties. [84] proposed improve the group decision algorithm and provide an application in handling the decision making problem. [85], text constructs the concept sequence interval-valued fuzzy soft sets, a comprehensive concept associating the mathematical model interval grey number sequences with the concept of interval-valued fuzzy soft sets.

Conclusions

The soft set theory of Molodtsov offers a general mathematical tool for dealing with uncertain, fuzzy, or vague objects. Molodtsov in has given several possible applications of soft set theory. Soft Sets represent a powerful instrument for decision making about information systems, data mining and drawing conclusions from data, especially in those cases where some uncertainty exists in the data. Its efficiency in dealing with uncertainty problems is as a result of its parameterized concept. In this paper, related to soft sets review of its existing literatures are collected. Finally, soft set has enough developed basic supporting structures. Many algebraic structures could be developed via this field.

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Conflict of interest

Authors declare there are no conflicts of interest.

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