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Bipolar Complex Fuzzy Soft Sets and Their Application

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ABSTRACT

The authors introduce a new computational model to solve efficient problems. This research generalizes the concept of bipolar fuzzy soft sets (BFSS) to the realm of complex numbers. However, the ranges of positive and negative values membership BFSS functions are extended to unit disk instead of [0, 1] and [-1, 0] respectively. The main benefit of bipolar complex fuzzy soft sets BCFSSs appears in the ability to transfer bipolar fuzzy soft information to a mathematical formula without losing the full meaning of information that may appear from different phases. Some basic operations and theorems on BCFSS are defined with numerical examples. This research has extended to illustrate the utilization of BCFSS in decision-making problems by generalizing the applications and algorithms.

KEYWORDS

Bipolar Complex Fuzzy Soft Sets, Bipolar Complex Fuzzy Soft Sets Operations, Bipolar Fuzzy Soft Sets, Complex Fuzzy Soft Sets, Fuzzy Soft Sets

1. INTRODUCTION

The fuzzy set (FS) has announced by the mid of the sixties by (Zadeh, 1965). It has been extensively considered, developed, and effectively applied to several grounds. Fuzzy sets and numbers can offer very good solutions in multi attributes in decision making (MADM) cases (Bellman & Zadeh, 1970; Yager, 1977). However, fuzzy sets failed to represent uncertain data being of several types owing to its limitation in convey information by only a single value that lies in [0, 1] so that the soft set (SS) came to overcome this limitation (Molodtsov, 1999). Further researches have shown strong attention in this method and several applications in MADM (Maji, et al. 2002; 2003; Ali et al., 2009; 2011;2012; Sezgin & Atagün, 2011; Jiang, et al., 2011; Min, 2012; Aktas & Çağman, 2007; Acar et al., 2010; Gong et al., 2010; Babitha & Sunil, 2010; Çağman & Engino'glu, 2010; Feng & Çağman, 2012). Due to the complication caused by the fuzzy nature of parameters in many situations, SS and FS were combined to formalize fuzzy soft sets (FSS) to deal with these situations (Maji et al., 2001). Therefore, some operations, new order relation, and decomposition finite value spaces of FSS are discussed (Borah et al., 2012; Guan et al., 2012; Feng et al., 2014).

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One more combination, bipolar fuzzy set (BFS) (Zhang, 1994) and SS innate a new notion named bipolar fuzzy soft set (BFSS) (Abdullaha et al., 2014) and they introduced fundamental properties and operations on the BFSS. An application and an algorithm of BFSS to solve decision-making problems were studied (Abdullaha et al., 2014). The bipolar fuzzy set (Zhang, 1994) has an exclusive property, which is the representing bipolar information "two-sided" about the given set (for instance: positive and negative, possible and impossible, Male and female, effect and side effect, etc.). The notion of BFS is an extension to FS (Zhang, 1994), in which the membership is extended from membership of degree in $\left[0,1\right]$ to a membership of degree in $\left[-1,0\right]\times\left[0,1\right]$ to indicate that the element satisfies somewhat an interesting property (Zhang et al., 2003;2004;2005;2006;2007;2009). Recently, some generalizations and applications in MADM, TOPSIS and VIKOR method were studied and genralized by using Bipolar fuzzy sets, Bipolar Fuzzy Soft Sets, Linear Diophantine Fuzzy Soft Rough Sets, and Linear Diophantine Fuzzy Sets see (Tehrim & Riaz, 2019; Riaz et. al., 2020; Riaz & Raza, 2019; Riaz &Tehrim, 2019; Riaz & Tehrim 2020, Mandal, 2021; Ali G, 2019; Tahir Mahmood. 2020).

On the stage of extending the codmain $\left[0,1\right]$ to unit disk in the complex plane, many researchers have been studied and applied the idea of generalizing several uncertainty sets from the real-valued interval $\left[0,1\right]$ to the realm of complex numbers (unit disk) in several fields, in (Tamir & Kandal,2011; Tamir et al., 2012b; Ramot et al., 2002; Rani & Grag, 2017; Sing, 2020; Al-Quran & Hassan, 2018; Alkouri et al., 2012;2013;2014; Li & Tu, 2019) Complex fuzzy set (CFS) is a fuzzy set described by a complex-valued membership function that the codomain lies in the unit disk in $\mathbb{C}$ (Ramot et al., 2002) . The phase of the grade of membership is denoted by $\theta\left(x\right)$, so without the phase term, the CFS reduces to traditional fuzzy set (Ramot et al., 2002). However, the idea of generalizing the codomain of fuzzy set to a wider codomain of complex fuzzy set lies in its ability to represent the semantics of uncertainty and periodicity information simultaneously. They were identifying the phase of degrees to distinguish the different meanings in different phases or levels for periodic data/degrees. Singh, P. K. (Singh, 2020) proposed recently the bipolar complex fuzzy concept lattice with its application and studied the problem which calculates the periodic variation in bipolar information at the given phase of time with three methods and illustrative examples for the suitable representation of bipolar complex data set. Singh represented the phase term in the complex fuzzy set as a real-valued component. In 2020, (Alkouri et al, 2020) introduced the notion of bipolar complex fuzzy sets (BCFS) and compared it with Singh's work. They studied the multiple attributes decision making (MADM) problem that measuring the "bipolarity of periodic" variation in bipolar information with an illustration example in order to find an optimal nutrition program for a person X.

Frequent factors with the perspective of bipolarity manipulate very important rules to provide proper selection methods in MADM problems, see (Alkouri et. al. 2020). Also, Soft set (Molodtsov, 1999) describes the objects without any restrictions on the set of parameters, with different types of parameters. CFS (Ramote et. al. 2002) offers wider range to represent the phase/ time on periodic data, thus, CFS covers the limitation of losing full meaning in the process of transferring the information from words to numbers and vice versa. These properties of precedes notions motivate us to introduce the current mathematical structure. This combination gives us the ability to treat and present special and wider type of information without losing full meaning. Also, this combination leads us to introduce a new algorithm solving many problems in MADM as illustrates in section 6. In this study, the authors conclude that some limitations in the ability of diverse uncertainty set to convey different types of information can be resolved by combining, extending and integrating these sets and their properties and overcome such limitations. A new combination and interpretation of bipolar complex fuzzy soft positive and negative membership grades are obtained, in which the bipolar complex fuzzy soft membership grade can be represented with two bipolar fuzzy soft components. By extending the range of bipolar fuzzy soft set (BFSS) to the realm of complex numbers,