

A APPENDICES

A.1 THE FOUND FUZZY SET EXTENSIONS WITH THE MOST COMMON KEYWORDS

Table A1: The found fuzzy set extensions with the most common keywords (RQ2, RQ3)^a

No	Fuzzy set extensions	Keywords
1	atanassov intuitionistic fuzzy set	group decision making (Garg and Kumar 2019), (Yang and Yao 2021), terminological difficulties (Bustince et al. 2016a), (Rahman 2016)
2	axiomatic fuzzy set	semantic interpretation (Wang et al. 2018; Jia et al. 2019; Shi and Zhao 2020), eigenfaces (Li et al. 2017), rough set model (Xu et al. 2023)
3	balanced fuzzy set	fuzzy neural network (Homenda and Pedrycz 2005), learning (Homenda and Pedrycz 2004), mcdm (Homenda et al. 2016)
4	bipolar fuzzy set	graph representation (Singh 2019a; Alkouri et al. 2020b), relational analysis method (Gao et al. 2018), terminological difficulties (Montero et al. 2016) (Bloch 2011), MULTIMOORA (Stanujkic et al. 2019), (Hu and Yiu 2024)
5	complex fuzzy set	granular computing (Singh 2019b), graph representation (Alkouri et al. 2020b), (Alkouri et al. 2020a), machine learning (Man et al. 2007; Yeganejou and Dick 2017), particle swarm optimization (Li and Tu 2019), mcdm (Ngan et al. 2018), (Gulistan and Khan 2019), (Selvachandran et al. 2022)
6	complex intuitionistic fuzzy set	mcdm (Gulzar et al. 2020), (Garg and Rani 2019)
7	complex pythagorean fuzzy sets	group decision making (Janani et al. 2022)
8	complex q-rung orthopair fuzzy set	topsis (Liu et al. 2021; Ajay et al. 2022)
9	convex fuzzy set	relational database (Bosc et al. 2003)
10	dynamic fuzzy sets	group decision making (Yoshida 1998), image segmentation (Nishimura et al. 1991; Solana-Cipres et al. 2009), medical diagnosis (Homenda and Pedrycz 2005), moving object detection (Solana-Cipres et al. 2009)
11	dual hesitant fuzzy set	group decision making (Shanghong and Ju 2015), madm (Yu 2014), mcdm (Yu 2015), topsis (Qua et al. 2017), correlation coefficient (Qu et al. 2019; Zhang 2020)
12	dual hesitant fuzzy soft set	correlation coefficient (He 2016; Zhang and He 2018), expert system (Garg and Arora 2018), mcdm (Arora and Garg 2018), medical diagnosis (Arora and Garg 2018)
13	eigen fuzzy sets	image analysis (Nobuhara et al. 2004), convex combination (Nobuhara et al. 2006)
14	fermatean fuzzy set	group decision making (Lai et al. 2022), mcdm (S 2021; Xu and Shen 2021), topsis (Xu and Shen 2021; Kirişci et al. 2022; Deng and Wang 2022), medical diagnosis (Ibrahim 2023), semigroups (Khan et al. 2022a)
15	fuzzy multiset	information fusion (De Miguel et al. 2017a), medical diagnosis (Bustince et al. 2016b; Ejegwa et al. 2022), terminological difficulties (Bustince et al. 2016b)
16	fuzzy rough set	information system (Yang et al. 2020a), machine learning (Daniel et al. 2021), object recognition (Pisharady et al. 2014), particle swarm optimization (Maini et al. 2019), 3-way decision (Yang et al. 2020a)
17	fuzzy soft set	normal parameter reduction (Chandrasekhar and Khare 2021)
18	general type-2 fuzzy set	karnik-mendel algorithm (Zhai and Mendel 2011; Kumbasar 2017), computing with words (Jiang 2018), controller (Gonzalez et al. 2019a), gene-expression data (Doostparast Torshizi and Fazel Zarandi 2014)
19	hesitant fuzzy linguistic term set	madm (Dong et al.), mcdm (Zhang and Xu 2014; Gou et al. 2017; Farhadinia and Herrera-Viedma 2018), topsis (Zhang and Xu 2014), vikor (Dong et al.), group decision making (Sarkar and Biswas)
20	hesitant fuzzy set	madm (Aggarwal 2019; Biswas et al. 2019), magdm (Zhu et al. 2016; Biswas et al. 2019), management (Zolfaghari and Mousavi 2018), mcdm (Jin 2015), mcgdm (Yang et al. 2020b), medical diagnosis (Farhadinia et al. 2021), multiplicative consistency (Zhang et al.), pattern recognition (Zeng et al. 2016b), quality function deployment (Liu et al. 2019a), supplier selection (Liu et al. 2019a), todim (Zhang et al. 2019b), topsis (Biswas et al. 2019; Liu et al. 2019a), vikor (Zolfaghari and Mousavi 2018; Biswas et al. 2019), 3-way decision (Liang et al. 2017), big data (Hao et al. 2021)
21	hesitant fuzzy soft set	madm (Suo et al. 2021), magdm (Beg and Rashid 2016; Riaz et al. 2020a), topsis (Beg and Rashid 2016), group decision making (Singh and Lalotra 2018)
22	interval neutrosophic hesitant fuzzy set	madm (Ye 2016), topsis (Giri et al. 2020), vikor (Giri et al. 2020), correlation coefficient (Liu and Shi 2015; Giri et al. 2020)
23	interval neutrosophic set	madm (Yang et al. 2018), mcdm (Şahin 2017; Yang et al. 2018), correlation coefficient (Şahin 2017)

No	Fuzzy set extensions	Keywords
24	interval type-2 fuzzy set	karnik-mendel algorithm (Mendel 2007; Kumbasar 2017), madm (Wang et al. 2017), magdm (Wang et al. 2015a), management (Mohagheghi et al. 2017; Zhong et al. 2020), mcda (Khalif et al. 2020), mcdm (Demircan and Tunc 2020), mcgdm (Dorfeshan et al. 2021), mobile robot (Jhang et al. 2019), neural network (Ouyang et al. 2014), particle swarm optimization (Sadiqbatcha et al. 2017), perceptual computing (Wu and Mendel 2010), qualiflex (Dincer and Yuksel 2019), risk management (Mohagheghi et al. 2017), software development (Chen 2001), stability analysis (Li et al. 2016), supplier selection (Gölcük et al. 2022), topsis (Zhong et al. 2020), tracking control (Kumbasar and Hagrass 2014), vikor (Liu et al. 2019b), best-worst method (Gölcük 2022), c-means algorithm (Dhar and Kundu 2020), controller (Wu and Mendel 2010), data envelopment analysis (Chen et al. 2022), dematel (Zhong et al. 2020; Gölcük et al. 2022), dynamic system (Li et al. 2014), edge-detection method (Ghozzi et al. 2022), facility location selection (Cebi and Otay 2015), fmea (Wang et al. 2019c), fuzzy multiple attributes group decision-making (Chen and Hong 2014), green supplier selection (Liu et al. 2019b), construction (Mirnezami et al. 2020)
25	interval-valued dual hesitant fuzzy set	madm (Zang et al. 2018), mcdm (Sarkar and Biswas 2020), topsis (Zang et al. 2017), correlation coefficient (Zang et al. 2017), group decision making (Li et al. 2018)
26	interval-valued fuzzy set	mcdm (Baležentis and Zeng 2013), prediction (Hajek 2018), terminological difficulties (Chen and Wang 2009), topsis (Liu et al. 2020a)
27	interval-valued hesitant fuzzy set	madm (Yuan et al. 2017), magdm (Zhang et al. 2014), mcdm (Zhang et al. 2017), pattern recognition (Kostadinov and Bureva 2022), topsis (Gitinavard et al. 2017), vikor (Mousavi 2021), correlation coefficient (Jin et al. 2016), green supplier selection (Mousavi 2021)
28	interval-valued intuitionistic fuzzy set	madm (He et al. 2020; Wang et al. 2022), magdm (Joshi and Kumar 2018), mcdm (Zhao et al. 2017), mcgdm (Çalı and Balaman 2019), pattern recognition (Kostadinov and Bureva 2022), programming (Li 2010), risk management (Otay and Jaller 2020), topsis (He et al. 2020), vikor (Wang and Li 2022), ahp (Otay and Jaller 2020), supplier selection (Yue 2019)
29	interval-valued pythagorean fuzzy set	mcdm (Al-Barakati et al. 2022), topsis (Peng and Li 2019)
30	interval-valued q-rung orthopair fuzzy set	madm (Gao and Xu 2019; Khan et al. 2021c), topsis (Gao et al. 2019; Khan et al. 2021c; Yang et al. 2022b), 3-way decision (Liang et al. 2022), aras (Jin et al. 2021), fmea (Jin et al. 2021), magdm (Gao et al. 2019), group decision making (Khan et al. 2021b)
31	interval-valued spherical fuzzy set	topsis (Kutlu Gündoğdu and Kahraman 2019), group decision making (Kutlu Gündoğdu and Kahraman 2019)
32	intuitionistic fuzzy rough sets	minimization (Zhou and Wu 2008; Zhou et al. 2009)
33	intuitionistic fuzzy set	expert system (Cholewa 2015), fault diagnosis (Sun et al. 2011), fmea (Zhu et al. 2018; Kushwaha et al. 2022), fuzzy c-mean (Dubey and Mushrif 2015), fuzzy clustering (Zhao et al. 2022), fuzzy neural network (Wang et al. 2023), fuzzy time series (Pant and Kumar 2022), anp (Afful-Dadzie et al. 2017), generalized nets (Sotirova et al. 2018), genetic algorithm (Li et al. 2019), gra (Rani et al. 2021), image processing (Guo and Zhou 2021), information system (Chatterjee et al. 2013), intuitionistic fuzzy c-means (Zhao et al. 2022), mabac (Zhu et al. 2018), madm (Seikh and Mandal 2021), magdm (Chu et al. 2019), magnetic resonance imaging (Zhao et al. 2022), mathematical programming (Chen 2011), matrix game (Li and Nan 2009; Li and Liu 2015; Nan et al. 2017), mcda (Chen 2011), mcdm (Afful-Dadzie et al. 2015), mcgdm (Liu et al. 2022c), medical diagnosis (Li 2004; Huang and Guo 2019), multimora (Zhang et al. 2019a), multiperson (Wei 2009; Chen 2011), neural network (Wang et al. 2023), particle swarm optimization (Kuo et al. 2018), pattern recognition (Deng et al. 2015; Ejegwa and Onyeke 2021), programming (Gupta et al. 2016), promethee (Liao and Xu 2014), quality (Sotirova et al. 2018), recommender system (Guo et al. 2019), renewable energy (Deveci et al. 2020), reputation (Wang 2012), risk management (Wang and Rani 2022), 3-way decision (Huang et al. 2020a), supplier selection (Kavita et al. 2009), supply chain (Liu et al. 2020c), todim (Zhang et al. 2022), topological spaces (Feng et al. 2009; Wu and Zhou 2011; Abbas 2021), topsis (Kavita et al. 2009; Wang and Rani 2022), vendor selection (Kavita et al. 2009), vikor (Geng and Liu 2015; Zhu et al. 2018; Zhang et al. 2022), correlation coefficient measure (Ejegwa and Onyeke 2021), covid-19 (Liu et al. 2022c), data envelopment analysis (Geng and Liu 2015), data mining (Nair 2009), decision support system (Seikh and Mandal 2021), dematel (Hinduja and Pandey 2019), electre (Qu et al. 2018)

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34	intuitionistic fuzzy soft set	gra (Chen and Zou 2017), group decision making (Zhang 2017)
35	l-fuzzy set	qualitative reasoning (Prats et al. 2014), topological spaces (Kortelainen 1997)
36	linguistic hesitant fuzzy set	madm (Meng et al. 2018), mcdm (Zhou et al. 2016), quality (Gong et al. 2021), todim (Gong et al. 2021), topsis (Guan et al. 2017), vikor (Dong et al. 2017), best-worst method (Gong et al. 2021), correlation coefficient (Guan et al. 2017; Meng et al. 2018), group decision making (Fahmi et al. 2021)
37	linguistic intuitionistic fuzzy set	madm (Cheng et al. 2021), magdm (Sarkar and Biswas; Kumar and Chen 2022), topsis (Ou et al. 2018), decision support model (Liang and Wang 2019), group decision making (Meng et al. 2019), sentiment analysis (Liang and Wang 2019), cognition (Liu et al. 2020d)
38	linguistic pythagorean fuzzy set	madm (Han et al. 2020), magdm (Rong et al. 2020; Khan et al. 2022b), mcgdm (Sarkar and Biswas 2021; Zhang et al. 2021), topsis (Garg 2018; Han et al. 2020; Sarkar and Biswas 2021), gra (Khan et al. 2022b), group decision making (Zeng et al. 2018; Lin et al. 2020)
39	m-polar fuzzy set	madm (Naeem and Divvaz 2022), topsis (Riaz et al. 2022), disease (Albahri et al. 2022), fuzzy concept lattice (Singh 2018), graph representation (Singh 2019c), multi-polar (Kazancı and Davvaz 2023)
40	multi-fuzzy set	diagnosis (Wang et al. 2015b)
41	multi-valued neutrosophic set	qualiflex (Peng et al. 2017b; Peng and Tian 2018), todim (Ji et al. 2018), correlation coefficient (Peng et al. 2017b, a), electre (Peng et al. 2017a), madm (Saqlain et al. 2020), mcdm (Peng et al. 2017a), mcgdm (Peng et al. 2015)
42	n-dimensional fuzzy sets	reciprocity (Bedregal et al.), cloud computing (Zanotelli et al. 2022), fuzzy negations (Mezzomo et al. 2018), information fusion (De Miguel et al. 2017b)
43	neutrosophic set	supplier selection (Zhang et al. 2020a), topsis (Nafei et al. 2021), vikor (Karaşan et al. 2019), group decision making (Zhang et al. 2020a), image segmentation (Chai et al. 2021)
44	neutrosophic soft set	todim (Yanmaz et al. 2020), topsis (Peng and Liu 2017; Naeem et al. 2020), vikor (Karaşan et al. 2019), correlation coefficient (Karaaslan 2017), edas (Peng and Liu 2017), group decision making (Naeem et al. 2020)
45	normal fuzzy set	todim (Şahin 2018), correlation coefficient (Şahin 2018), madm (Şahin 2018; Yang and Chang 2020)
46	paired fuzzy set	terminological difficulties (Montero et al. 2016)
47	picture fuzzy set	relational analysis method (Wei 2017; Ran 2021), todim (Ran 2021), topsis (Zhang et al. 2020b; Gül and Aydoğdu 2021), vikor (Singh and Kumar 2021), MCDM (Luo and Zhang 2023)
48	pythagorean fuzzy set	renewable energy (Xie et al. 2020), risk management (Li et al. 2020a), service quality (Zeng et al. 2016a; Ilbahar and Kahraman 2018), supplier selection (Wu et al. 2019), sustainability (Xie et al. 2020), todim (Sarkar and Biswas; Wang et al. 2019b; Ashraf et al. 2021), topsis (Thao and Smarandache 2019; Zhang et al. 2020c), vikor (Ming et al. 2020), waspas (Ilbahar and Kahraman 2018), biogeography-based optimization (Zheng et al. 2017), codas (Bolturk 2018), conflict analysis (Du et al. 2022), copras (Thao and Smarandache 2019), correlation coefficient measure (Ejegwa et al. 2021), deep learning (Zheng et al. 2017), dematel (Giri et al. 2022; Li et al. 2022), edas (Li et al. 2022), gra (Khan et al. 2020), green supplier selection (Wu et al. 2019), linmap (Chen 2019), management (Oztaysi et al. 2019), market volatility (Wang et al. 2019b), moora (Huang et al. 2020b), occupational-health (Demir and Karamaşa 2020), promethee (Chen 2018)
49	pythagorean fuzzy soft sets	topsis (Athira et al. 2019; Riaz et al. 2020b; Zulqarnain et al. 2021a), ahp (Zulqarnain et al. 2021b; Atalay et al. 2021), correlation coefficient (Zulqarnain et al. 2021a), madm (Zulqarnain et al. 2021a)
50	pythagorean hesitant fuzzy set	qualiflex (Jana and Roy 2023), topsis (Khan et al. 2017; Zhong et al. 2019), group decision making (Khan et al. 2017), mcdm (Zhong et al. 2019)
51	polygonal fuzzy set	rule interpolation (Cheng et al. 2015; Chen and Adam 2018a), sparse fuzzy rule-based systems (Cheng et al. 2015)
52	probabilistic fuzzy set	time series prediction [forecasting] (Gupta and Kumar 2019), (Chen and Adam 2018b), ann (Zhang et al. 2012a), c-means algorithm (Gupta and Kumar 2023), k-means clustering (Gupta and Kumar 2023), pattern classification (Zhang and Li 2011), controller (Zhang and Li 2011, 2012)
53	probabilistic hesitant fuzzy set	todim (Liao et al. 2022), vikor (Naeem et al. 2021; Krishankumar et al. 2021), correlation coefficient (Song et al. 2019), magdm (Jiang and Ma 2018)

No	Fuzzy set extensions	Keywords
54	q-rung orthopair fuzzy set	quality (Gong et al. 2020; Li et al. 2021), todim (Darko and Liang 2020), topsis (Wei et al. 2018; Garg et al. 2021; Liu et al. 2022a; Vimala et al. 2023), vikor (Khan et al. 2021a), 3-way decision (Liang and Cao 2019; Tang et al. 2020), correlation coefficient (Li et al. 2020b; Singh and Ganie 2022), mabac (Peng and Liu 2019), mcdm (Joshi and Gegov 2020; Ali and Naeem 2022), supplier selection (Mahmood and Ali 2021), inequalities (Peng et al. 2023)
55	random fuzzy set	bootstrap techniques (Ramos-Guajardo et al. 2013, 2014), c-means algorithm (Giordani and Ramos-Guajardo 2016), machine learning (Tansuchat et al. 2021)
56	rough fuzzy set	transformation-based interpolation (Chen et al. 2016), 3-way decision (Zhai et al. 2017; Zhai and Zhang 2018), decision systems (An et al. 2021), gaussian kernel (An et al. 2021), granular computing (Liu 2009; Małyszko and Stepaniuk 2009), inclusion degree (Sun and Gong 2007; Lee and Chang 2011; Zhang and Sun 2022), incremental learning (Huang et al. 2017), information system (Wu et al. 2006; Sun et al. 2017; Yu et al. 2019)
57	simplified neutrosophic set	correlation coefficient (Wu et al. 2016; Şahin and Zhang 2018), mcdm (Peng et al. 2014; Ye 2014a; Şahin and Liu 2017), medical diagnosis (Ye 2015; Abdel-Basset et al. 2021)
58	Single-valued neutrosophic set	topsis (Nancy and Garg 2019), ahp (Sodenkamp et al. 2018), correlation coefficient (Ye 2014b; Özlü 2023), madm (Mondal et al. 2018; Garai et al. 2020), magdm (Ye 2014c), mcdm (Ye 2014b; Ashraf et al. 2017), power average (Liu et al. 2019c)
59	spherical fuzzy set	todim (Liu et al. 2020b; Wu et al. 2020), correlation coefficient (Guleria and Bajaj 2021), madm (Kutlu Gündoğdu and Kahraman 2020), state-of-the-art (Ozceylan et al. 2022)
60	three-dimensional fuzzy set	controller design (Zhang et al. 2012b), distributed parameter system (Li et al. 2007), stability analysis (Zhang et al. 2010b, a)
61	type-1 fuzzy set	computing with words (Nusratov et al. 2017), facility location selection (Kahraman et al. 2003; Mokhtarian et al. 2014), fuzzy multiple attributes group decision-making (Chen et al.), karnik-mendel algorithm (Lim and Chan 2015; Chen et al. 2018), mcdm (Ponnialagan et al. 2018), perceptual computer (Wu 2014), recognition (Saha et al. 2018), topsis (Mokhtarian et al. 2014)
62	type-2 fuzzy set	vikor (Wang et al. 2019a), artificial intelligence (De Miguel et al. 2022), data envelopment analysis (Namvar and Bamdad 2021), data mining (Lin et al. 2016), edge detection (Gonzalez et al. 2019b), fuzzy ahp (Erdolan and Kaya 2016), fuzzy c-mean (Ji et al. 2014), fuzzy image processing (Castillo et al. 2017), granular computing (Al-Hmouz et al. 2018), hidden markov models (Zeng and Liu 2004), image processing (Castillo et al. 2017; Hussain and Jyotibora 2018), inference system (Huang et al. 2022), magdm (Chen and Kuo 2017), mcgdm (Liu et al. 2022b), medical diagnosis (Bustince et al. 2016c), mobile robot (Bencherif and Chouireb 2019), ontology (Lee et al. 2013), particle swarm optimization (Agarwal et al. 2014), regression model (Zou et al. 2018), risk management (Rao et al. 2017), social network (Naderipour et al. 2017), subtractive clustering (Ren et al. 2008; Ngo and Pham 2012), supplier selection (Hendiani et al. 2020), terminological difficulties (Bustince et al. 2016c; Yiyen et al. 2020)
63	typical hesitant fuzzy set	consistency (Matzenauer et al. 2022), correlation coefficient (Matzenauer et al. 2021), group decision making (Matzenauer et al. 2020)
64	t-spherical fuzzy set	topsis (Munir et al. 2021), correlation coefficient (Guleria and Bajaj 2021), madm (Al-Quran 2021), medical diagnosis (Guleria and Bajaj 2021), pattern recognition (Guleria and Bajaj 2021)
65	z-number	ahp (Alkan and Kahraman 2022), delphi (Lawnik and Banasik 2021), group decision making (Yang et al. 2022a), mcdm (Tavakkoli-Moghaddam et al. 2015), mobile robot (Abiyev et al. 2019), qualiflex (Wu et al. 2021), sustainability (Hoseini et al. 2020), topsis (Yaakob et al. 2018)

^a Note that all terms in Table A1 are presented as they are extracted from WoS and processed by VOSviewer.

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