2020 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE)

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2020 CONFERENCE PROCEEDINGS

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ISBN: 978-1-7281-6932-3
Part Number: CFP20FUZ-ART

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IEEE Catalog Number: CFP20FUZ-ART
ISBN: 978-1-7281-6932-3

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WELCOME MESSAGE FROM THE CHAIR

It is our pleasure to welcome you to the IEEE International Conference on Fuzzy Systems 2020 as part of the 2020 IEEE World Congress on Computational Intelligence (IEEE WCCI 2020). IEEE WCCI 2020 was planned to be held in Glasgow, Scotland, but unfortunately, all presentations will be given online due to the outbreak of Covid-19.

Professor Lotfi Zadeh believed that fuzzy logic, neurocomputing, and evolutionary computation should be collectively viewed as the main constituents of soft computing. His idea was that the combination of fuzzy logic, neural computing, and evolutionary computation will form a foundation for designing systems with high machine intelligence. Currently, IEEE World Congress on Computational Intelligence has become one of the most authoritative conferences on computational intelligence. IEEE International Conferences on Fuzzy Systems has consistently promoted solid theoretical advances, presented a host of successful applications, and nurtured an enormous potential yet to be realized in the future.

The FUZZ-IEEE 2020 conference provides a platform bringing together the researchers all over the world to work in a joint effort to push the research boundary and overcome emerging challenges. The program of FUZZ-IEEE 2020 reflects a rich variety of topics, from the foundations of fuzzy set theory, fuzzy reasoning, fuzzy modeling, fuzzy clustering, fuzzy control, to natural language processing, computational and artificial intelligence, cyber security, web intelligence, machine learning, lattice computing and emerging applications related to autonomous and robotics systems, classification, decision making, health monitoring and smart industry. Several papers are devoted to the state-of-the-art methods of fuzzy systems, neural and evolutionary computation, which is evidence of the importance of the soft computing approaches. The program also reflects the historic interest of the conference in the application of the theory of fuzzy sets and systems to data bases, data science, engineering, finance, and medicine. The number of submissions was 466 from 49 countries. The country assigned to the paper was the country from which its first author came. Of these, 259 were selected, 170 for oral presentations and 89 for poster presentation. The top 10 contributors by country are United Kingdom (12.9%), Spain (11.8%), Poland (11.3%), China (6.6%), Brazil (6.5%), Italy (5.0%), Australia (4.9%), United States (4.9%), France (4.1%), and India (3.9%). The strong number of submissions and world-wide contributions reflect a significant diving force and extensive effort from the fuzzy community to support the development of fuzzy research.

We are most grateful to the authors and plenary speakers for choosing FUZZ-IEEE to present their most recent results and advances, and for sharing their ideas. We want to express our deepest gratitude to the web review chair for supporting the review process, and to the reviewers for refereeing a considerable number of outstanding contributions. We extend our appreciation to the support team for their assistance. Particularly, I am most thankful to Amir, Xin, Marios, Nik, Oscar, Hani, Chin-Teng and to many other colleagues for their immeasurable help.

Hak-Keung Lam, FUZZ-IEEE Technical Co-Chair

MONDAY, JULY 20

Session F-MM1: Linguistic Summarization and Description of Data-I
Monday, July 20, 3:30PM-5:30PM, Room: FUZZ Room 1, Chair: Anna Wilbik, Daniel Sanchez, Nicolas Marin

3:30PM **TrPM: A Linguistic Petri Nets module to describe the trends of a time series [#22197]**
Juan Moreno-Garcia, Ester del Castillo and Luis Rodriguez-Benitez
Universidad de Castilla-La Mancha, Spain

3:50PM **Explaining Data Regularities and Anomalies [#22360]**
Amit Shukla, Gregory Smits, Olivier Pivert and Marie-Jeanne Lesot
Univ Rennes, IRISA, France; LIP6, Sorbonne Universite, France

4:10PM **Fuzzy Analytical Queries: A New Approach to Flexible Fuzzy Queries [#22475]**
Slawomir Zadrozny and Janusz Kacprzyk
Systems Research Institute Polish Academy of Sciences, Poland

4:30PM **A Preliminary Approach to Referring to Groups of Objects in Images [#22434]**
Nicolas Marin, Gustavo Rivas-Gervilla and Daniel Sanchez
University of Granada, Spain

4:50PM **Bipolar Queries and Relative Object Qualification in Scope of User-Assisted Database Querying [#22454]**
Mateusz Dziedzic, Guy De Tre, Janusz Kacprzyk and Slawomir Zadrozny
Dept. of Telecommunication and Information Processing, Ghent University, Ghent, Belgium, Belgium; Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland, Poland

5:10PM **Empirical Study of Fuzzy Quantification Models for Linguistic Descriptions of Meteorological Data [#22367]**
Carlos Heble-Lahera, Andrea Cascallar-Fuentes, Alejandro Ramos-Soto and Alberto Bugarin-Diz
Universidad Internacional Menendez Pelayo, Spain; Universidade de Santiago de Compostela, Spain

Session F-MM2: Human-in-the-Loop Interactions in Fuzzy Reasoning and Machine Learning
Monday, July 20, 3:30PM-5:30PM, Room: FUZZ Room 2, Chair: Jimmy Cao, CT Lin, Dongrui Wu

3:30PM **Privacy-Preserving Gesture Recognition with Explainable Type-2 Fuzzy Logic Based Systems [#22135]**
Josip Rozman, Hani Hagras, Javier Andreu-Perez, Damien Clarke, Beate Muller and Steve Fitz
University of Essex, United Kingdom; Plextek Ltd., United Kingdom

3:50PM **Knowledge extraction about patients surviving breast cancer treatment through an autonomous fuzzy neural network [#22074]**
Paulo Vitor Campos Souza, Yu-Kai Wang and Edwin Lughofer
JKU Linz, Austria; UTS, Australia

4:10PM **Data Imputation in Related Time Series Using Fuzzy Set-Based Techniques [#22232]**

Adam Kiersztyn, Pawel Karczmarek, Rafal Lopucki, Witold Pedrycz, Ebru Al, Ignacy Kitowski and Adam Zbyryt

Department of Computer Science Lublin University of Technology, Poland; Centre for Interdisciplinary Research The John Paul II Catholic University of Lublin, Poland; Department of Electrical & Computer Engineering University of Alberta Edmonton, Canada Department of Electrical and Computer Engineering King Abdulaziz University Jeddah, Saudi Arabia Systems Research Institute PAS, Warsaw, Poland, Poland; Ekol Lojistik Inc., Turkey; The State School of Higher Education in Chelm, Poland; The Polish Society for Bird Protection (PTOP), Poland

4:30PM **Multicriteria Decision Making: Scale, Polarity, Symmetry, Interpretability [#22157]**

Wladyslaw Homenda, Agnieszka Jastrzebska, Witold Pedrycz, Fusheng Yu and Yihan Wang

the Faculty of Mathematics and Information Science Warsaw University of Technology Warsaw, 00-662, Poland the Faculty of Economics and Informatics in Vilnius University of Bialystok LT-08221 Vilnius, Lithuania, Poland; the Faculty of Mathematics and Information Science Warsaw University of Technology Warsaw, 00-662, Poland, Poland; Systems Research Institute Polish Academy of Sciences Warsaw, 01-447, Poland Department of Electrical & Computer Engineering University of Alberta Edmonton T6R2G7AB, Canada, Canada; School of Mathematical Sciences Beijing Normal University Beijing 100875, China, China

4:50PM **A Demand-driven Proactive Tasks Management Model at the Edge [#22372]**

Anna Karanika, Panagiotis Oikonomou, Kostas Kolomvatsos and Thanasis Loukopoulos

University of Thesssaly, Greece; University of Thessaly, Greece; University of Athens, Greece

5:10PM **Novel Data Driven Fuzzy Algorithmic Volatility Forecasting Models with Applications to Algorithmic Trading [#22044]**

Aerambamoorthy Thavaneswaran, You Liang, Zimo Zhu and Ruppa K. Thulasiram

University of Manitoba, Canada; Ryerson University, Canada

Plenary Poster Session F-MM3: Software for Soft Computing-I

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Jose M. Alonso, Pietro Ducange, Riccardo Pecori and Raul Vilas

University of Santiago de Compostela, Spain; University of Pisa, Italy; University of Sannio, Italy

P102 **Chi-BD-DRF: Design of Scalable Fuzzy Classifiers for Big Data via A Dynamic Rule Filtering Approach [#22137]**

Fatemeh Aghaeipoor, Mohammad Masoud Javidi, Isaac Triguero and Alberto Fernandez

Shahid Bahonar University of Kerman, Iran; Computational Optimisation and Learning (COL) Lab, School of Computer Science, University of Nottingham, United Kingdom; University of Granada, Spain

P103 **Using SAT/SMT Solvers for Efficiently Tuning Fuzzy Logic Programs [#22465]**

Jose A. Riaza and Gines Moreno

University of Castilla-La Mancha, Spain

P104 **pyFUME: a Python Package for Fuzzy Model Estimation [#22308]**

Caro Fuchs, Simone Spolaor, Marco S. Nobile and Uzay Kaymak

Eindhoven University of Technology, Netherlands; University of Milano-Bicocca, Italy

P105 **FuzzyR: An Extended Fuzzy Logic Toolbox for the R Programming Language [#22228]**

Chao Chen, Tajul Razak and Jonathan Garibaldi

The University of Nottingham, United Kingdom; Universiti Teknologi MARA, Malaysia

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Pascual Julian-Iranzo and Fernando Saenz-Perez

University of Castilla-La Mancha, Spain; Complutense University of Madrid, Spain

Session F-MA1: Linguistic Summarization and Description of Data-II

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Anna Wilbik, Rick Gilsing, Oktay Turetken, Baris Ozkan and Paul Grefen

Eindhoven University of Technology, Netherlands

6:05PM On a Paradox of Extended Linguistic Summaries [#22251]

Anna Wilbik, Timothy Havens and Tim Wilkin

Eindhoven University of Technology, Netherlands; Michigan Technological University, United States; Deakin University, Australia

6:25PM A new method to measure the knowledge amount of Atanassov's intuitionistic fuzzy sets [#22052]

Hailin Zhang, Yafei Song, Lei Lei and Zhimin Qi

Academy of Milarity Sciences, China; Air Force Engineering University, China

6:45PM Perceptual Computing with Comparative Linguistic Expressions [#22198]

Taniya Seth and Pranab K. Muhuri

South Asian University, India

7:05PM XAI-Based Fuzzy SWOT Maps for Analysis of Complex Systems [#22349]

Zygimantas Meskauskas, Raimundas Jasinevicius, Egidijus Kazanavicius and Vytautas Petrauskas

Kaunas University of Technology, Lithuania

7:25PM Multilayer Fuzzy Extreme Learning Machine Applied to Active classification and Transport of objects using an Unmanned Aerial Vehicle [#22396]

Rolando Adonai Hernandez-Hernandez, Uriel Martinez-Hernandez and Adrian Rubio-Solis

Center for Engineering and Industrial Development, CIDESI, Mexico; University of Bath, United Kingdom

Session F-MA2: Advances on eXplainable Artificial Intelligence-I

Monday, July 20, 5:45PM-7:45PM, Room: FUZZ Room 2, Chair: Jose M. Alonso, Ciro Castiello, Corrado Mencar, Luis Magdalena

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Ilia Stepin, Jose M. Alonso, Alejandro Catala and Martin Pereira

University of Santiago de Compostela, Spain

6:05PM Interpreting Remaining Useful Life estimations combining Explainable Artificial Intelligence and domain knowledge in industrial machinery [#22207]

Oscar Serradilla, Ekhi Zugasti, Carlos Cernuda, Andoitz Aranburu, Julian Ramirez de Okariz and Urko Zurutuza

Mondragon Unibertsitatea, Spain; Fagor Arrasate, Spain; Koniker, Spain

6:25PM HFER: Promoting Explainability in Fuzzy Systems via Hierarchical Fuzzy Exception Rules [#22295]

Jose Ramon Trillo, Alberto Fernandez and Francisco Herrera

University of Granada, Spain

6:45PM **A Type-2 Fuzzy Logic Approach to Explainable AI for regulatory compliance, fair customer outcomes and market stability in the Global Financial Sector [#22095]**

Janet Adams and Hani Hagras

TSB Bank, United Kingdom; University of Essex, United Kingdom

7:05PM **An Interpretable Semi-supervised Classifier using Rough Sets for Amended Self-labeling [#22269]**

Isel Grau, Dipankar Sengupta, Maria M. Garcia Lorenzo and Nowe Ann

Vrije Universiteit Brussel, Belgium; Queens University Belfast, United Kingdom; Central University of Las Villas, Cuba

7:25PM **A preliminary study to apply the Quine McCluskey algorithm for fuzzy rule base minimization [#22298]**

Leonardo Jara, Antonio Gonzalez and Raul Perez

University of Granada, Spain

Plenary Poster Session F-MA3: Software for Soft Computing-II

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Pasquale D'Alterio, Jonathan Garibaldi, Robert John and Christian Wagner

University of Nottingham, United Kingdom

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Giovanni Acampora and Autilia Vitiello

University of Naples Federico II, Italy

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Giovanni Acampora, Roberta Siciliano and Autilia Vitiello

University of Naples Federico II, Italy

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Zack Ellerby, Oliver Miles, Josie McCulloch and Christian Wagner

University of Nottingham, United Kingdom

P305 **JKinect: A new Java Software for Designing and Assessing Gross Motor Activities in children with autism based on JFML [#22222]**

Gamez-Granados Juan Carlos, Rodriguez-Lozano Francisco Javier, Acampora Giovanni, Lee Chang-Shing and Soto-Hidalgo Jose Manuel

University of Cordoba, Spain; University of Naples Federico II, Italy; National University of Tainan, Taiwan; University of Granada, Spain

P306 **The Assessment of Importance of Selected Issues of Software Engineering, IT Project Management, and Programming Paradigms Based on Graphical AHP and Fuzzy C-Means [#22066]**

Pawel Karczmarek, Witold Pedrycz, Dariusz Czerwinski and Adam Kiersztyn

Department of Computer Science, Lublin University of Technology, Poland; Department of Electrical and Computer Engineering, University of Alberta, Canada

Session F-ME1: Special Session on Fuzzy and Rough Hybridisation

Monday, July 20, 8:00PM-10:00PM, Room: FUZZ Room 1, Chair: Yanpeng Qu, Neil Mac Parthalain, Richard Jensen

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Alicja Mieszkowicz-Rolka and Leszek Rolka
Rzeszow University of Technology, Poland

8:20PM **Fuzzy Rough Total Weighted Tardiness Flow Shop Scheduling Model with Hurwicz Criterion [#22417]**
Achraf Touil and Abdelwahed Echchtabi
Labotatory of Engineering, of Industrial Management and Innovation, FST, BP, Settat, Morocco

8:40PM **Constructing Belief Functions Using the Principle of Minimum Uncertainty [#22048]**
Yanyan He and Yousuff Hussaini
University of North Texas, United States; Florida State University, United States

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Nikita Neveditsin, Ross MacDonald, Trent Hillard and Pawan Lingras
Saint Mary's University, Canada; Green Power Labs Inc., Canada

9:20PM **Discovering Fuzzy Periodic-Frequent Patterns in Quantitative Temporal Databases [#22350]**
Uday kiran Rage, Sai Deep Chennupati, Ravi Kumar Penugonda, Koji Zettsu, Masaru Kitsuregawa and Krishna Reddy Polepalli
University of Tokyo, Japan; IIIT Hyderabad, India; RGUKT-AP, India; National Institute of Information and Communications Technology,Tokyo,Japan, Japan

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Zhiying Zhang, Huchang Liao and Abdullah Al-Barakati
Sichuan University, China; King Abdulaziz University, Saudi Arabia

Session F-ME2: Advances on eXplainable Artificial Intelligence-II
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8:00PM **An Improved Complexity Measure in Hierarchical Fuzzy Systems [#22169]**
Tajul Rosli Razak, Jonathan M. Garibaldi and Christian Wagner
Laboratory for Uncertainty in Data and Decision Making (LUCID), School of Computer Science, University of Nottingham, United Kingdom., United Kingdom

8:20PM **Constrained Interval Type-2 Fuzzy Classification Systems for Explainable AI (XAI) [#22318]**
Pasquale D'Alterio, Jonathan Garibaldi and Robert John
University of Nottingham, United Kingdom

8:40PM **Relevance of Using Interpretability Indexes for the Design of Schedulers in Cloud Computing Systems [#22347]**
Sebastian Garcia-Galan, Mouad Seddiki, Rocio Perez-Prado, Enrique Munoz-Exposito, Adam Marchewka and Nicolas Ruiz-Reyes
University of Jaen, Spain; University of Science and Technology, Poland

9:00PM **Hybrid Deep Learning Type-2 Fuzzy Logic Systems For Explainable AI [#22130]**
Ravikiran Chimatapu, Hani Hagras, Mathias Kern and Gilbert Owusu
University of Essex, United Kingdom; BT plc, United Kingdom

9:20PM **Interpretability and Explainability of LSP Evaluation Criteria [#22042]**
Jozo Dujmovic
San Francisco State University, United States

9:40PM **An Interpretable Fuzzy System in the On-line Signature Scalable Verification [#22283]**
Marcin Zalasinski, Krzysztof Cpalka and Krystian Lapa
Czestochowa University of Technology, Poland

Plenary Poster Session F-ME3: AGGREGATION STRUCTURES: NEW TRENDS AND APPLICATIONS
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P501 **An Empirical Study on Supervised and Unsupervised Fuzzy Measure Construction Methods in Highly Imbalanced Classification [#22355]**
Mikel Uriz, Daniel Paternain, Humberto Bustince and Mikel Galar
Public University of Navarre, Spain

P502 **A Proposal of the Notions of Ordered and Strengthened Ordered Directional Monotonicity for Interval-valued Functions Based on Admissible Orders [#22315]**
Mikel Sesma-Sara, Radko Mesiar, Javier Fernandez, Zdenko Takac and Humberto Bustince
Public University of Navarra, Spain; Slovak University of Technology, Slovakia

P503 **Conditioned Monotonicity for Generalized Pre-Aggregations and Aggregations [#22179]**
Luis Magdalena, Daniel Gomez, Javier Montero, Susana Cubillo and Carmen Torres
Universidad Politecnica de Madrid, Spain; Complutense University of Madrid, Spain

P504 **Generalizing the GMC-RTOPSIS Method using CT-integral Pre-aggregation Functions [#22226]**
Jonata Cristian Wieczynski, Gracaliz Pereira Dimuro, Eduardo Nunes Borges, Giancarlo Lucca, Helida Salles Santos, Rodolfo Lourenzutti and Humberto Bustince
Universidade Federal do Rio Grande, Brazil; University of British Columbia, Canada; Universidad Publica de Navarra, Spain

P505 **Extended Linear Order Statistic (ELOS) Aggregation and Regression [#22230]**
Siva Krishna Kakula, Anthony Pinar, Timothy Havens and Derek Anderson
Michigan Technological University, United States; University of Missouri, United States

P506 **A note on the links between different qualitative integrals [#22216]**
Michal Holcapek and Agnes Rico
University of Ostrava, Czech Republic; Universite lyon 1, France

TUESDAY, JULY 21

Session F-TM1: Fuzzy Logic in Knowledge Graphs and Factor Space
Tuesday, July 21, 2:30PM-4:30PM, Room: FUZZ Room 1, Chair: Zongmin Ma, Jing He, Pei Ho-Chung, Luihuang Wang

2:30PM **An Innovative Fuzzy Logic-Based Machine Learning Algorithm for Supporting Predictive Analytics on Big Transportation Data [#22483]**
Carson K. Leung, Jonathan D. Elias, Shael M. Minuk, Alddous Roy R. de Jesus and Alfredo Cuzzocrea
University of Manitoba, Canada; University of Calabria, Italy

2:50PM **Querying Fuzzy RDF Knowledge Graphs Data [#22208]**
Li Guanfeng, Li Weijun and Wang Hairong
College of Information Engineering, Ningxia University, China; College of Computer Science & Engineering, North Minzu University, China

3:10PM **Fuzzy Sugeno \lambda-Measures and Theirs Applications to Community Detection Problems [#22334]**
Inmaculada Gutierrez, Daniel Gomez, Javier Castro and Rosa Espinola
Complutense University, Spain

3:30PM **Factor space is the adaptive and deepening theory of fuzzy sets [#22254]**
Haitao Liu, Runjun Wan, Shanshan Xue, Tiantian Wang, Sizong Guo and Jing He
Liaoning Technical University, China; University of Maastricht, Netherlands; Swinburne University of Technology, Australia

3:50PM **Retrieving Sparser Fuzzy Cognitive Maps Directly from Large Ordinal Dataset using Lasso Graphical Models and the MAX-threshold Algorithm [#22240]**
Zoumpolia Dikopoulou, Elpiniki Papageorgiou and Koen Vanhoof
Hasselt University, Belgium; University of Thessaly, Greece

4:10PM **A Fuzzy Theory Based Topological Distance Measurement For Undirected Multigraphs [#22266]**
Jing He, Jinjun Chen, Guangyan Huang, Mengjiao Guo, Zhiwang Zhang, Hui Zheng, Yunyao Li, Ruchuan Wang, Weibei Fan, Chi-Huang Chi, Weiping Ding, Paulo A.de Souza, Bin Chen, Runwei Li, Shang Jie and Andre Van Zundert
Swinburne University of Technology, Australia; Deakin University, Australia; Nanjing University of Finance and Economics, China; Nanjing University of Posts and Telecommunications, China; Data 61, CSIRO, Australia; Nantong University, China; Griffith University, Australia; Ningbo Institue of Materials Technology and Engineering, Chinese Academy of Sciences, China; Royal Brisbane & Women's Hospital, Australia

Session F-TM2: Fuzzy Interpolation
Tuesday, July 21, 2:30PM-4:30PM, Room: FUZZ Room 2, Chair: Qiang Shen, Laszlo T. Koczy, Shyi-Ming Chen

2:30PM **Dynamic TSK Systems Supported by Fuzzy Rule Interpolation: An Initial Investigation [#22132]**
Pu Zhang and Qiang Shen
Faculty of Business and Physical Sciences, Aberystwyth University, United Kingdom

2:50PM **Process of Inversion in Fuzzy Interpolation Model using Fuzzy Geometry [#22391]**
Suman Das, Debjani Chakraborty and Laszlo T. Koczy
Indian Institute of Technology Kharagpur, India; Budapest University of Technology, Hungary

3:10PM **Fuzzy Rulebase Parameter Determination for Stabilized Koczy-Hirota Interpolation Based Detection of Colorectal Polyps on Colonoscopy Images [#22280]**

Brigita Sziova, Raneem Ismail, Ferenc Lilik, Laszlo T. Koczy and Szilvia Nagy

Szechenyi Istvan University, Hungary; Szechenyi Istvan University, Budapest University of Technology and Economics, Hungary

3:30PM **Image Super Resolution with Sparse Data Using ANFIS Interpolation [#22133]**

Muhammad Ismail, Yang Jing, Shang Changjing and Shen Qiang

Dept. of Computer Science, Aberystwyth University, Aberystwyth, Ceredigion, Wales, United Kingdom

3:50PM **On the Properties of Orderings of Extensional Fuzzy Numbers [#22293]**

Martin Stepnicka, Nicole Skorupova and Michal Holcapek

University of Ostrava, Czech Republic

4:10PM **From arithmetics of extensional fuzzy numbers to their distances [#22310]**

Martin Stepnicka, Nicole Skorupova and Michal Holcapek

University of Ostrava, Czech Republic

Plenary Poster Session F-TM3: Recent Advances in Fuzzy Control System Design and Analysis-I

Tuesday, July 21, 2:30PM-4:30PM, Room: FUZZ Poster Room, Chair: Kevin Guelton, Zsofia Lendek

P701 **Set-Invariance Based Fuzzy Output Tracking Control for Vehicle Autonomous Driving under Uncertain Lateral Forces and Steering Constraints [#22188]**

Anh-Tu Nguyen, Marie-Thierry Guerra, Jagat Rath, Hui Zhang and Reinaldo Palhares

Laboratory LAMIH UMR CNRS 8201, Universite Polytechnique Hauts-de-France, France; Technische Universitat Munchen, Germany; Beihang University, China; Federal University of Minas Gerais, France

P702 **Controller design for time-delay TS fuzzy systems with nonlinear consequents [#22279]**

Amalia Matyas, Zoltan Nagy and Zsofia Lendek

Technical University of Cluj-Napoca, Romania

P703 **Switched Control for Local Stabilization of Discrete-time Uncertain Takagi-Sugeno Fuzzy Systems with Relaxed Estimate of the Domain of Attraction [#22363]**

Gilberto Rodrigues dos Santos, Diogo Ramalho de Oliveira, Marcelo Carvalho Minhoto Teixeira, Edvaldo Assuncao, Rodrigo Cardim and Adalberto Zanatta Neder Lazarini

Federal University of Mato Grosso do Sul, Campus of Pantanal, Brazil; Federal Institute of Education, Science and Technology of Mato Grosso do Sul, Brazil; Sao Paulo State University, School of Engineering, Department of Electrical Engineering, Brazil

P704 **Framework for Mining Hybrid Automata from a Constrained Machine Learning Architecture [#22134]**

Matthew Clark and Kuldip Rattan

Galois Inc, United States; Wright State University, United States

P705 **Event-Triggered Interval Type-2 Fuzzy Control for Uncertain Space Teleoperation Systems with State Constraints [#22425]**

Ziwei Wang, Hak-Keung Lam, Zhang Chen, Bin Liang and Tao Zhang

Tsinghua University, China; King's College London, United Kingdom

P706 **Admissibility Analysis and Robust Stabilization via State Feedback for Uncertain T-S Fuzzy Descriptor Systems [#22051]**

Jiabao He, Feng Xu, Xueqian Wang and Bin Liang

Tsinghua Shenzhen International Graduate School, China; Tsinghua University, China

Session F-TA1: Handling Uncertainties in Big Data By Fuzzy Systems-I
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4:45PM **Wildfire Prediction: Handling Uncertainties Using Integrated Bayesian Networks and Fuzzy Logic [#22237]**
Mohsen Naderpour, Hossein Mojaddadi Rizeei and Fahimeh Ramezani
University of Technology Sydney (UTS), Australia

5:05PM **An Improved Deep Convolutional Fuzzy System for Classification Problems [#22357]**
Huidong Wang and Jinli Yao
Shandong University of Finance and Economics, China

5:25PM **A Novel Non-parametric Two-Sample Test on Imprecise Observations [#22448]**
Feng Liu, Guangquan Zhang and Jie Lu
Centre for Artificial Intelligence, Faculty of Engineering and Information Technology, University of Technology Sydney, Australia

5:45PM **A Fuzzy Drift Correlation Matrix for Multiple Data Stream Regression [#22369]**
Yiliao Song, Guangquan Zhang, Lu Haiyan and Lu Jie
University of Technology Sydney, CAI, Australia

6:05PM **Acoustic Event Detection Using Fuzzy Integral Ensemble and Oriented Fuzzy Local Binary Pattern Encoded CNN [#22261]**
Achyut Mani Tripathi and Rashmi Dutta Baruah
Indian Institute of Technology Guwahati, India

6:25PM **A Parabolic Based Fuzzy Data Envelopment Analysis Model with an Application [#22296]**
Mohammad Aqil Sahil, Meenakshi Kaushal and Q.M. Danish Lohani
South Asian University, India

Session F-TA2: Computational Intelligence methods for Natural Language Processing
Tuesday, July 21, 4:45PM-6:45PM, Room: FUZZ Room 2, Chair: Joao Paulo Carvalho

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Vania Mendonca, Alberto Sardinha, Luisa Coheur and Ana Lucia Santos
INESC-ID, Portugal; CLUL, Portugal

5:05PM **Relevance Ranking for Web Search [#22312]**
Joao Lages, Joao Paulo Carvalho and Joao Paulo Carvalho II
INESC-ID / Instituto Superior Tecnico, Portugal

5:25PM **Interpreting Human Responses in Dialogue Systems using Fuzzy Semantic Similarity Measures [#22121]**
Naeemeh Adel, Keeley Crockett, David Chandran and Joao Carvalho
Manchester Metropolitan University, United Kingdom; Kings College London, United Kingdom; Universidade de Lisboa, Portugal

5:45PM **Using Fuzzy Set Similarity in Sentence Similarity Measures [#22126]**
Valerie Cross, Valeria Mokrenko, Keeley Crockett and Naeemeh Adel
Miami University, United States; Manchester Metropolitan University, United Kingdom

6:05PM **An OWA and Aspect-based approach applied to Rating Prediction [#22147]**
Jesus Serrano-Guerrero, Francisco P. Romero and Jose A. Olivas
University of Castilla-La Mancha, Spain

6:25PM **Summarizer: Fuzzy Rule-Based Classification Systems for Vertical and Horizontal Big Data [#22429]**

Petala Tuy and Tatiane Rios

Federal University of Bahia, Brazil

Plenary Poster Session F-TA3: Recent Advances in Fuzzy Control System Design and Analysis-II

Tuesday, July 21, 4:45PM-6:45PM, Room: FUZZ Poster Room, Chair: Kevin Guelton, Zsofia Lendek

P901 **Adaptive LAMDA applied to identify and regulate a process with variable dead time [#22149]**

Luis Morales, David Pozo, Jose Aguilar and Andres Rosales

Escuela Politecnica Nacional, Ecuador; Universidad de las Americas, Ecuador; Universidad de Los Andes, Venezuela

P902 **A Design Approach for General Type-2 Fuzzy Logic Controllers with an Online Scheduling Mechanism [#22277]**

Ahmet Sakalli, Tufan Kumbasar and Jerry Mendel

AVL Research and Engineering, Turkey; Istanbul Technical University, Turkey; University of Southern California, United States

P903 **Reachable Set Boundedness and Fuzzy Sliding Mode Control of MPPT for Nonlinear Photovoltaic Systems [#22144]**

Zhixiong Zhong, Xingyi Wang, Rathinasamy Sakthivel and Chih-Min Lin

Minjiang University, China; Bharathiar University, India; Yuan Ze University, Taiwan

P904 **Generalized Stochastic Petri-Net Algorithm with Fuzzy Parameters to Evaluate Infrastructure Asset Management Policy [#22122]**

Swati Sachan and Nishant Donchak

The University of Manchester, United Kingdom; LNG Quest Limited, United Kingdom

P905 **f-HybridMem: A Fuzzy-based Approach for Decision Support in Hybrid Memory Management [#22384]**

Rodrigo Moura, Guilherme Schneider, Lizandro Oliveira, Mauricio Pilla, Adenauer Yamin and Renata Reiser

Federal University of Pelotas, Brazil

P906 **Computational Intelligence and Automated Methods for Control Fuzzy System Design [#22177]**

Milan Todorovic and Milan Simic

RMIT University, Australia

Session F-TE1: Handling Uncertainties in Big Data By Fuzzy Systems-II

Tuesday, July 21, 7:00PM-9:00PM, Room: FUZZ Room 1, Chair: Hua Zuo, Jie Lu, Guangquan Zhang

7:00PM **Monwatch: A fuzzy application to monitorize the user behavior using wearable trackers [#22235]**

Carmen Martinez-Cruz, Javier Medina Quero, Jose Maria Serrano and Sergio Gramajo

Departamento of Computer Science. University of Jaen. Jaen, Spain, Spain; National Technological University. Resistencia, Argentina, Argentina

7:20PM **Possibilistic Approach for Novelty Detection in Data Streams [#22423]**

Tiago Pinho da Silva and Heloisa Camargo

Universidade de Sao Paulo, Brazil; Universidade Federal de Sao Carlos, Brazil

7:40PM **Fuzzy Multivariate Outliers with Application on BACON Algorithm [#22336]**

Huda Touny, Ahmed Moussa and Ali Hadi

Faculty of Computers and Artificial Intelligence, Egypt; American University in Cairo, Egypt

8:00PM **Fuzzy Aggressive Behavior Assessment of Toxic Players in Multiplayer Online Battle Games [#22111]**

Guilherme Andrigueto and Ernesto Araujo

Universidade Anhembi-Morumbi, Brazil

8:20PM **Experiments with Maximin Sampling [#22027]**

Omar Ibrahim, James Keller, James Bezdek and Mihail Popescu

Electrical Engineering and Computer Science Department, University of Missouri-Columbia, United States; Health Management and Informatics Department, University of Missouri-Columbia, United States

8:40PM **Fuzzy c-Means with Improved Particle Swarm Optimization [#22212]**

Jie Li and Yasunori Endo

Department of Risk Engineering, University of Tsukuba, Japan; Faculty of Engineering, Information and Systems, University of Tsukuba, Japan

Session F-TE2: Recent trends in many-valued logic and fuzziness

Tuesday, July 21, 7:00PM-9:00PM, Room: FUZZ Room 2, Chair: Pietro Codara, Stefano Aguzzoli, Diego Valota

7:00PM **On the representation of (weak) nilpotent minimum algebras [#22401]**

Umberto Rivieccio, Tommaso Flaminio and Thiago Nascimento da Silva

Universidade Federal do Rio Grande do Norte, Brazil; Instituto de Investigacion en Inteligencia Artificial, Spain

7:20PM **Automorphism Groups of Lindenbaum Algebras of Some Propositional Many-Valued Logics with Locally Finite Algebraic Semantics [#22273]**

Stefano Aguzzoli

Universita' degli Studi di Milano, Italy

7:40PM **On k-Lipschitzian (T,N)-implications [#22276]**

Suene Campos, Jocivania Pinheiro, Benjamin Bedregal and Anderson Cruz

Universidade Federal Rural do Semi-Arido, Brazil; Universidade Federal do Rio Grande do Norte, Brazil

8:00PM **Fuzzy Number Value or Defuzzified Value; Which One Does It Better? [#22338]**

Amir Pourabdollah

Nottingham Trent University, United Kingdom

8:20PM **Universal Stone Duality via the Concept of Topological Dualizability and its Applications to Many-Valued Logic [#22463]**

Yoshihiro Maruyama

The Australian National University, Australia

8:40PM **N-ary norm operators and TOPSIS [#22047]**

Pasi Luukka

LUT University, Finland

Plenary Poster Session F-TE3: Interval and Fuzzy-valued Functions and their Applications
Tuesday, July 21, 7:00PM-9:00PM, Room: FUZZ Poster Room, Chair: Manuel Arana-Jimenez, Maria Letizia Guerra, Laerte Sorini, Luciano Stefanini

P1101 Midpoint Representation of Fuzzy-Valued Functions and Applications [#22191]
Benedetta Amicizia, Mina Shahidi, Laerte Sorini, Luciano Stefanini and Maria Letizia Guerra
University of Urbino, Italy; University of Bologna, Italy

P1102 On Frechet and Gateaux derivatives for interval and fuzzy-valued functions in the setting of generalized Hukuhara differentiability [#22194]
Luciano Stefanini and Manuel Arana-Jimenez
University of Urbino, Italy; University of Cadiz, Spain

P1103 Methods of ranking for aggregated fuzzy numbers from interval-valued data [#22209]
Justin Gunn, Hadi Khorshidi and Uwe Aickelin
The University of Melbourne, Australia

P1104 Comparing Intervals Using Type Reduction [#22025]
Thomas Runkler, Chao Chen, Simon Coupland and Robert John
Siemens AG, Germany; University of Nottingham, United Kingdom; De Montfort University, United Kingdom

P1105 Fuzzy Interval Modelling based on Joint Supervision [#22322]
Diego Munoz-Carpintero, Sebastian Parra, Oscar Cartagena, Doris Saez, Luis G. Marin and Igor Skrjanc
Universidad de O'Higgins, Chile; University of Chile, Chile; Universidad de Los Andes, Colombia; University of Ljubljana, Slovenia

P1106 Interval-Valued Fuzzy c-Means Algorithm and Interval-Valued Density-Based Fuzzy c-Means Algorithm [#22378]
Ayush K. Varshney, Priyanka Mehra, Pranab K. Muhuri and Q. M. Danish Lohani
South Asian University, India

WEDNESDAY, JULY 22

Session F-WM1: Type-2 Fuzzy Logic Systems
Wednesday, July 22, 3:30PM-5:30PM, Room: FUZZ Room 1, Chair: Oscar Castillo, Patricia Melin, Pranab Muhuri, Amit Shukla

3:30PM **On the relationship between the centroid and the footprint of uncertainty of Interval Type-2 fuzzy numbers [#22403]**
Juan Carlos Figueroa Garcia, Roman Neruda, Yurilev Chalco Cano and Heriberto Roman Flores
Universidad Distrital Francisco Jose de Caldas, Colombia; Czech Academy of Sciences, Czech Republic; Universidad de Tarapaca, Chile

3:50PM **Optimal Design of Interval Type-2 Fuzzy Tracking Controllers of Mobile Robots using a Metaheuristic Algorithm [#22480]**
Felizardo Cuevas, Oscar Castillo and Prometeo Cortes
Tijuana Institute of Technology, Mexico

4:10PM **A Type 2 Fuzzy Genetic Approach to Uncertain and Dynamic Resilient Routing within Telecommunications Networks [#22107]**
Lewis Veryard, Hani Hagras, Anthony Conway and Gilbert Owusu
The University of Essex, United Kingdom; British Telecom, United Kingdom

4:30PM **A Big Bang Big Crunch Type-2 Fuzzy Logic System for Explainable Semantic Segmentation of Trees in Satellite Images using HSV Color Space [#22105]**
Hugo Leon-Garza, Hani Hagras, Anasol Pena-Rios, Anthony Conway and Gilbert Owusu
University of Essex, United Kingdom; British Telecom, United Kingdom

4:50PM **An Interval Type-2 Fuzzy Dynamic Approach To Replacement of Server Equipment [#22328]**
Esra Cakir and Ziya Ulukan
Galatasaray University, Turkey

5:10PM **Intermediary Fuzzification in Speech Emotion Recognition [#22053]**
Gustavo Assuncao and Paulo Menezes
University of Coimbra, Portugal

Session F-WM2: Distributed/Multiagent Control of Fuzzy and Intelligent Systems
Wednesday, July 22, 3:30PM-5:30PM, Room: FUZZ Room 2, Chair: Mohammad Akbarzadeh, Fahimeh Baghbani

3:30PM **Combining Consensus and Tracking Errors in Sliding Mode Control of High Order Uncertain Stochastic Multi-Agent Systems [#22067]**
Pooya Parsa and Mohammad Reza Akbarzadeh-Totonchi
Department of Electrical Engineering, Center of Excellence on Soft Computing and Intelligent Information Processing, Ferdowsi University of Mashhad, Iran; Ferdowsi University of Mashhad, Iran

3:50PM **Decentralized Distribution of UAV Fleets Based on Fuzzy Clustering for Demand-driven Aerial Services [#22449]**
Maria Joao Sousa, Alexandra Moutinho and Miguel Almeida
IDMEC, Instituto Superior Tecnico, Universidade de Lisboa, Lisboa, Portugal, Portugal; Center for Forest Fire Research, ADAI, University of Coimbra, Coimbra, Portugal, Portugal

4:10PM **Robust Reference Tracking Control Design for Stochastic Polynomial Fuzzy Control System: A Sum-of-Squares Approach [#22136]**

Min-Yen Lee and Bor-Sen Chen

National Tsing Hua University, Taiwan

4:30PM **Autonomous Driving of Truck-Trailer Mobile Robots with Linear-Fuzzy Control for Trajectory Following [#22413]**

Antonio Moran and Masao Nagai

Pontifical Catholic University of Peru, Peru; Tokyo University of Agriculture and Technology, Japan

4:50PM **Predictive Control Based on Fuzzy Optimization for Multi-Room HVAC Systems [#22302]**

Alvaro Endo, Oscar Cartagena, Doris Saez and Diego Munoz-Carpintero

University of Chile, Chile; Universidad de O'Higgins, Chile

5:10PM **A Competitive Swarm Algorithm for Image Segmentation Guided by Opposite Fuzzy Entropy [#22069]**

Mohamed Abd Elaziz, Ahmed A. Ewees, Dalia Yousri, Diego Oliva, Songfeng Lu and Erik Cuevas

School of cyber science and Engineering, Huazhong university of Science and Technology, China; Damietta University, Egypt; Fayoum University, Egypt; Universidad de Guadalajara, CUCEI, Mexico

Plenary Poster Session F-WM3: Fuzziness and New Frontiers of AI Research

Wednesday, July 22, 3:30PM-5:30PM, Room: FUZZ Poster Room, Chair: Irina Perfilieva, Marek Reformat

P1301 **Additional Feature Layers from Ordered Aggregations for Deep Neural Networks [#22354]**

Iris Dominguez, Daniel Paternain and Mikel Galar

Public University of Navarre, Spain

P1302 **F-Transform and Convolutional NN: Cross-Fertilization and Step Forward [#22337]**

Vojtech Molek and Irina Perfilieva

Ostrava University, Czech Republic

P1303 **Interpreting Variational Autoencoders with Fuzzy Logic: A step towards interpretable deep learning based fuzzy classifiers [#22379]**

Kutay Bolat and Tufan Kumbasar

Istanbul Technical University, Turkey

P1304 **A Situation-aware Learning System based on Fuzzy Cognitive Maps to increase Learner Motivation and Engagement [#22406]**

Giuseppe D'Aniello, Massimo De Falco, Matteo Gaeta and Mario Lepore

University of Salerno, Italy; CORISA, Italy

P1305 **A New Aggregation Operator for Intuitionistic Fuzzy Sets with Applications in Risk Estimation and Decision Making [#22079]**

Hoang Nguyen

Gdynia Maritime University, Poland

P1306 **Quantitative Study of Fuzzy Logics [#22030]**

Zofia Kostrzycka and Marek Zaionc

University of Technology, Opole, Poland; Theoretical Computer Science, Jagiellonian University, Krakow, Poland

Plenary Poster Session F-WA1: Human Symbiotic Systems
Wednesday, July 22, 5:45PM-7:45PM, Room: FUZZ Room 1, Chair: Tomohiro Yoshikawa, Yoichiro Maeda

P1501 Design of the convolution layer using HDL and evaluation of delay time using a camera signal [#22271]
Ryoki Kamesaka and Yukinobu Hoshino
Kochi University of Technology, Japan; Kochi University of technology, Japan

P1502 Development and validation of the lane-keeping controller using a similarity-type fuzzy reasoning method [#22438]
Yuka Nishiyama, Yuki Shinomiya, Toshimi Yamamoto and Yukinobu Hoshino
Kochi University of Technology, Japan; Kochi University of technology, Japan

P1503 Ensemble Learning Based on Soft Voting for Detecting Methamphetamine in Urine [#22450]
Kurnianingsih Kurnianingsih, Nur Fajri Al Faridi Hadi, Eni Dwi Wardihani, Naoyuki Kubota and Wei Hong Chin
Department of Electrical Engineering, Politeknik Negeri Semarang, Indonesia; Graduate School of Systems Design, Tokyo Metropolitan University, Japan

P1504 Development of Smart Device Interlocked Robot Partners for Information Support and Smart Recommendation [#22331]
Shion Yamamoto and Naoyuki Kubota
Tokyo Metropolitan University, Japan

P1505 A Pythagorean Fuzzy Preference Relation Approach for Group Decision Making [#22141]
Zhang Hengshan, Chen Tianhua, Wang Zhongmin, Chen Yanping and Chen Chunru
Xian University of Posts and Telecommunications, China; University of Huddersfield, United Kingdom

P1506 An Incremental Algorithm for Granular Counting with Possibility Theory [#22214]
Corrado Mencar
University of Bari "Aldo Moro", Italy

Session F-WA2: Fuzzy Logic for Security and Forensics
Wednesday, July 22, 5:45PM-7:45PM, Room: FUZZ Room 2, Chair: Nitin Naik

5:45PM A New Approach to Fuzzy Regular Expression Parsers for Cybersecurity Logs [#22464]
Trevor Martin, Alex Healing and Ben Azvine
University of Bristol, United Kingdom; BT, United Kingdom

6:05PM Embedding Fuzzy Rules with YARA Rules for Performance Optimisation of Malware Analysis [#22411]
Nitin Naik, Paul Jenkins, Nick Savage, Longzhi Yang, Kshirasagar Naik and Jingping Song
University of Portsmouth, United Kingdom; Northumbria University, United Kingdom; University of Waterloo, Canada; Northeastern University, China

6:25PM Fuzzy-Import Hashing: A Malware Analysis Approach [#22477]
Nitin Naik, Paul Jenkins, Nick Savage, Longzhi Yang, Tossapon Boongoen and Natthakan Iam-On
University of Portsmouth, United Kingdom; Northumbria University, United Kingdom; Mae Fah Luang University, Thailand

6:45PM Heat-Map Based Occupancy Estimation Using Adaptive Boosting [#22163]
Abdallah Naser, Ahmad Lotfi, Junpei Zhong and Jun He
Nottingham Trent University, United Kingdom

7:05PM **Cooperative Adaptive Fuzzy Control of Uncertain Affine Nonlinear Multi-agent Systems Based on Artificial Potential Functions [#22201]**

Fahimeh Baghbani and Mohammad Reza Akbarzadeh-T.

Department of Electrical Engineering, Center of Excellence on soft computing and intelligent information processing, Ferdowsi University of Mashhad, Iran

7:25PM **The Concept of Detecting and Classifying Anomalies in Large Data Sets on a Basis of Information Granules [#22233]**

Adam Kiersztyn, Pawel Karczmarek, Krystyna Kiersztyn and Witold Pedrycz

Department of Computer Science Lublin University of Technology, Poland; Department of Mathematical Modeling The John Paul II Catholic University of Lublin, Poland; Department of Electrical & Computer Engineering University of Alberta Edmonton, Canada

Session F-WA3: Advanced Fuzzy Robotic Systems

Wednesday, July 22, 5:45PM-7:45PM, Room: FUZZ Poster Room, Chair: Ching-Chih Tsai

5:45PM **Mixed Gaussian Membership Functions Fuzzy Cerebellar Model Articulation Controller Design for Robotic Manipulators [#22145]**

Tuan-Tu Huynh, Chih-Min Lin, Tien-Loc Le and Zhixiong Zhong

Yuan Ze University, Taiwan; Lac Hong University, Viet Nam; Minjiang University, China

6:05PM **3D Object Detection and 6D Pose Estimation Using RGB-D Images and Mask R-CNN [#22057]**

Van Luan Tran and Huei-Yung Lin

National Chung Cheng University, Taiwan

6:25PM **Multi-robot exploration using Dynamic Fuzzy Cognitive Maps and Ant Colony Optimization [#22116]**

Marcio Mendonca, Rodrigo H C Palacios, Elpiniki I Papageorgiou and Lucas Botoni de Souza

Universidade Tecnologica Federal do Parana, Brazil; University of Thessaly Larisa, Greece, Greece

6:45PM **Swarm Collective Wisdom: A Fuzzy-Based Consensus Approach for Evaluating Agents Confidence in Global States [#22371]**

Aya Hussein, Sondoss Elsawah and Hussein A. Abbass

UNSW Canberra, Australia

7:05PM **Milk-run Routing and Scheduling Subject to Fuzzy Pickup and Delivery Time Constraints: An Ordered Fuzzy Numbers Approach [#22058]**

Grzegorz Bocewicz, Zbigniew Banaszak, Katarzyna Rudnik, Marcin Witczak, Czeslaw Smutnicki and Jaroslaw Wikarek

Koszalin University of Technology, Poland; Opole University of Technology, Poland; University of Zielona Gora, Poland; Wroclaw University of Science and Technology, Poland; Kielce University of Technology, Poland

7:25PM **Fuzzy Set-Based Isolation Forest [#22065]**

Pawel Karczmarek, Adam Kiersztyn and Witold Pedrycz

Department of Computer Science, Lublin University of Technology, Poland; Department of Electrical and Computer Engineering, University of Alberta, Canada

Session F-WE1: Intuitionistic Fuzzy Sets in Emerging Domains

Wednesday, July 22, 8:00PM-10:00PM, Room: FUZZ Room 1, Chair: Danish Lohani, Pranab K. Muhuri

8:00PM **Attribute Selection for Sets of Data Expressed by Intuitionistic Fuzzy Sets [#22394]**

Eulalia Szmidt, Janusz Kacprzyk and Pawel Bujnowski

Systems Research Institute Polish Academy of Sciences, Poland

8:20PM **Interval-valued Intuitionistic Fuzzy TOPSIS method for Supplier Selection Problem [#22469]**

Ashutosh Tiwari, Q M Danish Lohani and Pranab K. Muhuri

South Asian University, India

8:40PM **Improved Probabilistic Intuitionistic Fuzzy c-Means Clustering Algorithm: Improved PIFCM [#22259]**

Ayush K. Varshney, Q. M. Danish Lohani and Pranab K. Muhuri

South Asian University, India

9:00PM **On ordinal sums of t-norms and t-conorms on bounded posets [#22142]**

Antonin Dvorak, Michal Holcapek and Jan Paseka

University of Ostrava, Czech Republic; Masaryk University, Czech Republic

9:20PM **The Use of Concave and Convex Functions to Optimize the Feed-Rate of Numerically Controlled Machine Tools [#22160]**

Pekala Barbara, Rak Ewa, Kwiatkowski Bogdan, Szczur Adam and Rak Rafal

University of Rzeszow, Poland

9:40PM **A new family of Bonferroni mean-type pre-aggregation operators [#22178]**

Swati Rani Hait, Radko Mesiar, Debashree Guha and Debjani Chakraborty

Indian Institute of Technology Kharagpur, India; Slovak University of Technology, Slovakia

Session F-WE2: Fuzzy and Uncertain Intelligent Knowledge Engineering Systems

Wednesday, July 22, 8:00PM-10:00PM, Room: FUZZ Room 2, Chair: Jerry Chun-Wei Lin

8:00PM **Mining Multiple Fuzzy Frequent Patterns with Compressed List Structures [#22129]**

Jerry Chun-Wei Lin, Jimmy Ming-Tai Wu, Youcef Djenouri, Gautam Srivastava and Tzung-Pei Hong

Western Norway University of Applied Sciences, Norway; Shandong University of Science and Technology, China; SINTEF Digital, Mathematics and Cybernetics, Norway; Brandon University, Canada; National University of Kaohsiung, Taiwan

8:20PM **One-Phase Temporal Fuzzy Utility Mining [#22248]**

Hong Tzung-Pei, Lin Cheng-Yu, Huang Wei-Ming, Li Shu-Min, Wang Shyue-Liang and Lin Jerry Chun-Wei

Department of Computer Science and Information Engineering National University of Kaohsiung, Taiwan; Department of Computer Science and Engineering National Sun Yat-sen University, Taiwan; Department of Computing, Mathematics, and Physics Western Norway University of Applied Science, Norway

8:40PM **A Novel Meta Learning Framework for Feature Selection using Data Synthesis and Fuzzy Similarity [#22343]**

Zixiao Shen, Xin Chen and Jonathan Garibaldi

University of Nottingham, United Kingdom

9:00PM **Toward the use of Quantile Fuzzy Transforms for the Construction of Fuzzy Association Rules [#22270]**

Nicolas Madrid

University of Malaga, Spain

9:20PM **AI-based Decision-making Model for the Development of a Manufacturing Company in the context of Industry 4.0 [#22162]**

Justyna Patalas-Maliszewska, Iwona Pajak and Malgorzata Skrzeszewska

Institute of Mechanical Engineering University of Zielona Gora, Poland

9:40PM Fuzzy Set Similarity for Feature Selection in Classification [#22054]

Valerie Cross, Michael Zmuda, Rahul Paul and Lawrence Hall

Miami University, United States; University of South Florida, United States

Plenary Poster Session F-WE3: Fuzzy systems for robotics

Wednesday, July 22, 8:00PM-10:00PM, Room: FUZZ Poster Room, Chair: Ching-Chih Tsai

P1701 A Novel Self-Organizing PID Approach for Controlling Mobile Robot Locomotion [#22028]

Xiaowei Gu, Muhammad Aurangzeb Khan, Plamen Angelov, Bikash Tiwary, Elnaz Shafipour Yourdshah and Zhao-Xu Yang

Lancaster University, United Kingdom; Xi'an Jiaotong University, China

P1702 A New Fuzzy Logic Based Adaptive Motion Cueing Algorithm Using Parallel Simulation-Based Motion Platform [#22064]

Mohamad Reza Chalak Qazani, Houshyar Asadi, Tobias Bellmann, Siamak Pedrammehr, Shady Mohamed and Saeid Nahavandi

Institute for Intelligent System Research and Innovation, Deakin University, Australia, Australia; Institute of System Dynamics and Control, Space Systems Dynamics, Deutsches Zentrum fur Luft- und Raumfahrt (DLR) German Aerospace Center, Germany, Germany; Institute for Intelligent Systems Research and Innovation (IISRI), Deakin University, Australia; Institute for Intelligent Systems Research and Innovation (IISRI), Deakin University, Austria

P1703 Design of Low-Cost Fuzzy Controllers with Reduced Parametric Sensitivity Based on Whale Optimization Algorithm [#22183]

Radu-Codrut David, Radu-Emil Precup, Stefan Preitl, Alexandra-Iulia Szedlak-Stinean, Raul-Cristian Roman and Emil M. Petriu

Politehnica University of Timisoara, Romania; School of Electrical Engineering and Computer Science, Canada

P1704 An Evolutionary General Type-2 Fuzzy Neural Network applied to Trajectory Planning in Remotely Operated Underwater Vehicles [#22184]

Adrian Rubio-Solis, Tomas Salgado-Jimenez, Luis Govinda Garcia-Valdovinos, Luciano Nava-Balanzar, Uriel Martinez-Hernandez and Rolando Adonai Hernandez-Hernandez

Center for Engineering and Industrial Development, CIDESI, Mexico; University of Bath, United Kingdom

P1705 Staircase Traversal via Reinforcement Learning for Active Reconfiguration of Assistive Robots [#22272]

Andrei Mitriakov, Panagiotis Papadakis, Sao Mai Nguyen and Serge Garlatti

Lab-STICC, UMR 6285 F-29238, team RAMBO, IMT Atlantique, Brest, France, France

P1706 A Virtual Fuzzy Actuator for the Fault-tolerant Control of a Rescue Vehicle [#22102]

Ralf Stetter

Ravensburg-Weingarten University (RWU), Germany

THURSDAY, JULY 23

Session F-THM1: Fuzzy Systems for Brain Sciences
Thursday, July 23, 3:30PM-5:30PM, Room: FUZZ Room 1, Chair: CT Lin, Javier Perez, Amit Konar, Mukesh Prasad

3:30PM **P200 and N400 Induced Aesthetic Quality Assessment of an Actor Using Type-2 Fuzzy Reasoning [#22281]**
Mousumi Laha, Amit Konar, Madhuparna Das, Chandrima Debnath, Nandita Sengupta and Atulya K. Nagar
Jadavpur University, India; University College of Bahrain, Bahrain; Liverpool Hope University, Liverpool, United Kingdom

3:50PM **A Neuro-Fuzzy Based Approach for Resting-state Detection Using A Consumer-grade EEG [#22383]**
Angelo Ciaramella and Salma Pasquale Junior
Universita' degli Studi di Napoli Parthenope, Italy; Universita' degli Studi di Napoli Parthenopeiversita' degli Studi di Napoli Parthenope, Italy

4:10PM **A type-2 Fuzzy Logic Based Explainable Artificial Intelligence System for Developmental Neuroscience [#22340]**
Mehrin Kiani, Javier Andreu-Perez, Hani Hagras, Maria Laura Filippetti and Silvia Rigato
University of Essex, United Kingdom

4:30PM **Fuzzy Neural Networks to Detect Parkinson Disease [#22402]**
Lerina Aversano, Mario Luca Bernardi, Marta Cimitile and Riccardo Pecori
University of Sannio, Italy; Unitelma Sapienza University, Italy

4:50PM **Fuzzy Divergence Based Analysis For EEG Drowsiness Detection Brain Computer Interfaces [#22341]**
Tharun Kumar Reddy, Vipul Arora, Laxmidhar Behera, Yukai Wang and Chin Teng Lin
PhD student, EE department, iit kanpur, India; Assistant Professor, EE department, iit kanpur, India; Professor, EE department, iit kanpur, India; Lecturer, UTS, Australia, Australia; Distinguished Professor, UTS, Australia, Australia

5:10PM **Manipulating Focal Sets on the Unit Simplex: Application to Plastic Sorting [#22229]**
Lucie Jacquin, Abdelhak Imoussaten, Sebastien Destercke, Francois Trousset, Jacky Montmain and Didier Perrin
EuroMov Digital Health in Motion IMT Mines Ales, Univ Montpellier, France; Sorbonne universites, UTC CNRS, Heudiasyc, France; Laboratoire des Science des Risque (LSR) IMT Mines Ales, France; Polymers Composites and Hybrids (PCH) IMT Mines Ales, France

Session F-THM2: SenseAgents: Soft Approaches in Multi-sensing Cooperative Environments
Thursday, July 23, 3:30PM-5:30PM, Room: FUZZ Room 2, Chair: Sabrina Senatore, Mario Cimino, Wen Dong

3:30PM **A Fuzzy Logic Based System for Cloud based Building Information Modelling Rendering Optimization in Augmented Reality [#22106]**
Hugo Leon-Garza, Hani Hagras, Anasol Pena-Rios, Gilbert Owusu and Anthony Conway
University of Essex, United Kingdom; British Telecom, United Kingdom

3:50PM **Towards a Layered Agent-modeling of IoT Devices to Precision Agriculture [#22342]**
Danilo Cavaliere, Vincenzo Loia and Sabrina Senatore
University of Salerno, Italy

4:10PM **Exploring Brazilian Photovoltaic Solar Energy Development Scenarios using the Fuzzy Cognitive Map Wizard Tool [#22306]**

Konstantinos Papageorgiou, Gustavo Carvalho, Elpiniki Papageorgiou, Nikolaos Papandrianos, Marcio Mendonca and George Stamoulis

Department of Computer Science and Telecommunications,University of Thessaly, Lamia, Greece; Faculty of Economics, Business Administration and Accounting University of Sao Paulo (USP), Brazil; Department of Energy Systems, Faculty of Technology University of Thessaly, Geopolis Campus, Greece; Electrical Engineering Academic Dept (DAELE)Universidade Tecnologica Federal do Parana, Brazil; Dept. of Electrical and Computer Engineering,University of Thessaly, Greece

4:30PM **Asset Operation Detection Based on Fuzzy Logic and Phase Portrait [#22405]**

Cody Xiaozhan Yang, Faiyaz Doctor, Mohammad Hossein Anisi, Mohammadreza Khosravi, Ian Parry and Patryk Wegrzyn

The University of Essex, Cloudfm Group Ltd and Mindsett Ltd, United Kingdom; The University of Essex, United Kingdom; Cloudfm Group Ltd and Mindsett Ltd, United Kingdom

4:50PM **Detection of Road Artefacts Using Fuzzy Adaptive Thresholding [#22124]**

Marcin Badurowicz, Jerzy Montusiewicz and Pawel Karczmarek

Lublin University of Technology, Department of Computer Science, Poland

5:10PM **AI-FML Agent for Robotic Game of Go and AIoT Real-World Co-Learning Applications [#22193]**

Chang-Shing Lee, Yi-Lin Tsai, Mei-Hui Wang, Wen-Kai Kuan, Zong-Han Ciou and Naoyuki Kubota

National University of Tainan, Taiwan; Tokyo Metropolitan University, Japan

Plenary Poster Session F-THM3: Fuzzy Engineering Applications-I

Thursday, July 23, 3:30PM-5:30PM, Room: FUZZ Poster Room, Chair: Krzysztof Dyczkowski

P1901 **The ordering methods of interval-valued fuzzy cardinal numbers with application in an uncertain decision making [#22182]**

Krzysztof Dyczkowski, Barbara Pekala, Michal Baczynski, Jaroslaw Szkola and Tomasz Pilka

Adam Mickiewicz University, Poland; University of Rzeszow, Poland; University of Silesia, Poland

P1902 **Robust actuator and sensor fault estimation for Takagi-Sugeno fuzzy systems under ellipsoidal bounding [#22268]**

Marcin Witczak, Marcin Pazera, Norbert Kukurowski, Teodulo Ivan Bravo Cruz and Theilliol Didier

University of Zielona Gora, Poland; National Technological Institute of Mexico, Mexico; Universite de Lorrain, France

P1903 **Accelerometer-based Human Fall Detection Using Fuzzy Entropy [#22117]**

Aadel Howedi, Ahmad Lotfi and Amir Pourabdollah

Nottingham Trent University, United Kingdom

P1904 **Effective Diagnosis of Heart Disease Imposed by Incomplete Data Based on Fuzzy Random Forest [#22267]**

Elzhan Zeinulla, Karina Bekbayeva and Adnan Yazici

Nazarbayev University, Kazakhstan

P1905 **Using Dempster-Shafer Theory for RSS-based Indoor Localization [#22387]**

Achour Achroufene, Abdelghani Chibani and Yacine Amirat

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Clemson University, United States

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Department of Electronic and Computer Engineering, Universidad de Cordoba, Spain; Instituto de Microelectronica de Sevilla (IMSE-CNM), Universidad de Sevilla, CSIC, Spain

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Cranfield University, United Kingdom; University of Sheffield, United Kingdom

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Bart Kosko

University of Southern California, United States

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Systems Research Institute Polish Academy of Sciences Warsaw, 01-447, Poland and Department of Electrical & Computer Engineering University of Alberta, Edmonton T6R2G7AB, Canada, Canada; the Faculty of Mathematics and Information Science Warsaw University of Technology Warsaw, 00-662, Poland and the Faculty of Economics and Informatics in Vilnius University of Bialystok LT-08221 Vilnius, Lithuania, Poland; the Faculty of Mathematics and Information Science Warsaw University of Technology Warsaw, 00-662, Poland, Poland; School of Mathematical Sciences Beijing Normal University Beijing 100875, China, China

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Marcin Korytkowski, Rafal Scherer, Dominik Szajerman, Dawid Polap and Marcin Wozniak
Czestochowa University of Technology, Poland; Lodz University of Technology, Poland; Silesian University of Technology, Poland

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Jerry Mendel
University of Southern California, United States

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Universidad Publica de Navarra, Spain; Universidade Federal do Rio Grande, Brazil; Universidade Federal do Rio Grande do Norte, Brazil

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University of Rzeszow, Poland; Universidad Publica de Navarra, Spain

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University of Rzeszow, Poland

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Labotatory of Engineering, of Industrial Management and Innovation, FST, BP, Settat, Morocco

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Przemyslaw Grzegorzewski

Warsaw University of Technology, Poland

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University of Granada, Spain

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Zoumpolia Dikopoulou, Elpiniki Papageorgiou and Koen Vanhoof
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Hongmei He, John Gray, Angelo Cangelos, Qinggang Meng, Martin Mcginnity and Jorn Mehnen
Cranfield University, United Kingdom; University of Manchester, United Kingdom; Loughborough University, United Kingdom; Nittongham Trent University, Ulster University, United Kingdom; University of Strathclyde, United Kingdom

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Omid Orang, Rodrigo Silva, Petronio Candido de Lima e Silva and Frederico Gadelha Guimaraes

UFMG, Brazil; UFOP, Brazil; IFNMG, Brazil

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Edward Hinojosa, Edgar Sarmiento and Heloisa Camargo

Universidad Nacional de San Agustin de Arequipa, Peru; Federal University of Sao Carlos, Brazil

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Perez-Martinez Ignacio, Martinez-Rojas Maria and Soto-Hidalgo Jose Manuel

University of Cordoba, Spain; University of Malaga, Spain; University of Granada, Spain

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Nottingham Trent University, United Kingdom

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University of Campinas (Unicamp), Brazil

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Assiut University, Egypt; University of Louisville, United States; Mansoura University, Egypt

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Amiyangshu De, Mousumi Laha, Amit Konar and Atulya K Nagar

Indian Institute of Technology Jodhpur, India; Jadavpur University, India; Liverpool Hope University, United Kingdom

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Gloria Cerasela Crisan, Camelia-M. Pintea and Petrica C. Pop

Faculty of Sciences, Vasile Alecsandri University, Bacau, Romania; Faculty of Sciences, Technical University Cluj-Napoca, Baia-Mare, Romania

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Pedro Manuel Martinez-Jimenez, Jesus Chamorro-Martinez and Belen Prados-Suarez
University of Cadiz, Spain; University of Granada, Spain

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LIMOS, UCA, France, France; Digital Health Hub, SFU, Canada, Canada

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Siva Krishna Kakula, Anthony Pinar, Timothy Havens and Derek Anderson
Michigan Technological University, United States; University of Missouri, United States

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Luyi Bai, Jiajia Lu and Shuangdi Wang
Northeastern University, China

P2703 **Fuzzy aggregation for multimodal remote sensing classification [#22125]**
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US Naval Research Laboratory, United States

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The University of Manchester, United Kingdom; Kennedys Law LLP, United Kingdom

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Lublin University of Technology, Poland; The State School of Higher Education in Chelm, Poland; Centre for Interdisciplinary Research The John Paul II Catholic University of Lublin, Poland; The Polish Society for Bird Protection (PTOP), Poland

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Fatima Chiroma and Ella Haig

University of Portsmouth, United Kingdom

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Josie McCulloch, Zack Ellerby and Christian Wagner

University of Leeds, United Kingdom; University of Nottingham, United Kingdom

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Abdelhak Imoussaten, Pierre Couturier and Jacky Montmain

IMT Mines Ales, France

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University of Rzeszow, Poland

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University of Missouri, United States; Deakin University, Australia

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Jose M. Alonso, Javier Toja-Alamancos and Alberto Bugarin

Universidade de Santiago de Compostela, Spain

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Syed Manzar Abbas, Khubaib Amjad Alam and Kwang-Man Ko

Department of Computer Science, National University of Computer and Emerging Sciences, Pakistan, Pakistan; Department of Computer Engineering, Sangji University, Republic of South Korea, Korea, Republic of

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Kohei Yamamoto, Shuai Shao and Naoyuki Kubota

Tokyo metropolitan University, Japan; Tokyo Metropolitan University, Japan

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Ignacio Huitzil, Umberto Straccia, Carlos Bobed, Eduardo Mena and Fernando Bobillo

University of Zaragoza, Spain; ISTI-CNR, Italy; everis / NTT Data, Spain; I3A, University of Zaragoza, Spain

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Jesus Chamorro-Martinez, Miriam Mengibar-Rodriguez and James M. Keller

University of Granada, Spain; University of Missouri, United States

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Debasmita Banerjee, Debashree Guha and Radko Mesiar

Indian Institute of Technology Patna, India; Indian Institute of Technology Kharagpur, India; Slovak University of Technology, Slovakia

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Universidad de La Laguna, Spain

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Priyanka Mehra, Taniya Seth and Pranab K. Muhuri

South Asian University, India

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Empirical study of fuzzy quantification models for linguistic descriptions of meteorological data

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***Abstract*—In this work we present an experimental comparison of six widely used quantification methods (Zadeh's scalar and fuzzy cardinality, Yager's OWA, Delgado's GD, Sugeno integral and Vila's VQ) when evaluating Type-1 and Type-2 linguistic descriptions of data generated from meteorological data provided by the Galician Meteorological Agency MeteoGalicia. The objective of this study is to evaluate if there are significant differences among these models for the data considered. We ranked the generated descriptions based on their degree of truth for each quantification model and we analyzed those results calculating the Pearson correlation coefficient. Results show that there are not significant differences in the models when evaluating Type-1 descriptions. However, in Type-2 evaluation the methods can be grouped in three clusters with a significantly different behavior among them: *i)* Zadeh's scalar cardinality, Delgado's GD and Zadeh's fuzzy cardinality, *ii)* Yager's method and *iii)* Vila's VQ.**

***Index Terms*—fuzzy quantification, linguistic descriptions of data, natural language generation**

I. Introduction

Nowadays, the analysis and interpretation of data is becoming an increasingly difficult task for humans due to its exponential growth. Therefore, computational methods that can perform these tasks are in high demand.

In the natural language generation field (NLG), many systems have been developed in order to generate comprehensible texts with useful information from several data sources [1].

Besides, in the fuzzy logic field, several approaches were proposed to generate data descriptions using linguistic terms. Following Zadeh's computing with words and perceptions paradigms [2], [3], linguistic descriptions of data (LDD) [4] summarize in a linguistic form one or more numerical variables and their values, using the general notion of protoform [5]. These protoforms can follow several structure types (e.g temporal or comparative [6], [7]), being Type-1 and Type-2 fuzzy quantified statements [8]–[10] with absolute or relative quantifiers the most common in the literature (e.g. *"In some places the temperature is low"*).

Type-1 descriptions have the following structure: *"Q X are A"*, where Q is a linguistic quantifier, X is a linguistic variable defined on a given referential and A is a fuzzy linguistic value (property) of X. For instance, in *"Most temperatures are normal," "Most"* is the quantifier, *"temperatures"* is the linguistic variable and *"normal"* is a linguistic value of *temperatures*. Type-2 descriptions follow the structure *"Q DX are A"* where an additional fuzzy property *"D"* is defined on the same referential of X. For example, in *Most temperatures in the North are normal "North"* is the additional fuzzy property (D).

Relative quantifiers express the proportion of elements over the total which fulfill a condition, e.g *"**half** locations have low temperature"*. Absolute quantifiers express quantities over the total of elements which fulfill a condition, e.g *"**15** locations have low temperature"*.

Evaluating a quantified sentence involves obtaining its truth value (a value in the range [0, 1]) on a given data set. It is obtained by calculating the compatibility between the number of elements in the referential which fulfill the sentence (its cardinality) and the quantifier in the sentence. Therefore, this compatibility measure depends on the data, the quantifier definition and the linguistic terms defined from the properties in the referential. Besides, it also depends on the quantification model used for evaluating the sentence. There exist several quantification methods [11]–[16] in the literature that differ from each other in the way they calculate the truth value.

The aim of this work is to experimentally compare six widely used quantification methods for the evaluation of Type-1 and Type-2 quantified descriptions, in order to assess their empirical behavior when applied for the evaluation of fuzzy quantified sentences. To generate these descriptions we use meteorological data provided by the Galician (NW Spain) Meteorological Agency (MeteoGalicia) [17].

Our objective in this work is to perform a comparison among the selected fuzzy quantification models described in Section II with the aim of analyze the correlation between them when evaluating type-1 and type-2 quantified statements. If differences between the methods behavior are detected, the selection of a fuzzy quantification model for a specific case should take this difference into consideration. Conversely, if the results show a similar behavior between the models, the selection of a fuzzy quantification model for an specific case should follow another criteria (e.g., its theoretical properties or computational cost).

This paper is structured as follows: in Section II we describe the methods included in this experimentation. In Section III we describe the used data set and the definition of the linguistic variables for the quantified sentences generation. In Section IV we describe the experiments we performed for comparing the quantification methods behavior. Finally, Section V includes some final remarks.

978-1-7281-6932-3/20/$31.00 ©2020 IEEE

II. Fuzzy quantification methods

In this section, we present the set of quantification methods empirically compared in this study. The selection of these methods rely on their presence in the literature and their different cardinalities, since this feature can have such a great impact on the quantification methods performance.

The first approaches for fuzzy quantification were proposed by Zadeh [11], who identified the need of extending the concept of the quantifiers *exist* and *all* to other imprecise ones, with more expressiveness.

Evaluating a quantified sentence involves calculating its truth value. In this evaluation, two aspects have to be considered: *i)* the (fuzzy or scalar) cardinality, i.e., how many elements in the referential fulfill belong to the fuzzy set defined from a variable and *ii)* the compatibility between the cardinality measure and the quantifier. Quantification models differ in the type of cardinality and in how the compatibility is evaluated.

Several studies [15], [16], [18]–[21] theoretically analyzed quantification methods by checking the properties they fulfill. These analysis show that, in general, quantifiers should behave (very) differently, although, for Type-1 descriptions and coherent[1] quantifiers, it was theoretically proved [14] that GD [14] is a generalization of Yager's method [12] and ZS [15] is a generalization of the Sugeno integral base method [13].

Aiming to go beyond of these theoretical results, to the best of our knowledge, there are no experimental analysis that assess the behavior of quantification models from an empirical point of view.

A. Type-1 models

As indicated in the previous sections, Type-1 descriptions follow the "Q X are A" protoform.

1) Zadeh's method: [11] is based on the scalar cardinality "power" defined by Zadeh as $P(A) = \sum_{i=1}^{n} A(x_i)$.

The evaluation of Type-1 sentences for relative quantifiers is defined (for the t-norm minimum, the most popular operator used in the literature) as:

$$Z_Q(A) = Q\left(\frac{P(A)}{|X|}\right) \tag{1}$$

2) Yager's method based on OWA operators: [12] can only be used with coherent and relative quantifiers. The evaluation is:

$$Y_Q(A) = \sum_{i=1}^{n} A(w_i b_i) \tag{2}$$

where b_i is the i-th higher value of the degree of truth to the fuzzy set A and w_i a coefficient obtained between the quantifier and $|X|$ to ensure that the evaluation is coherent.

[1]A quantifier Q is called coherent (or monotonically nondecreasing quantifiers [12]) if $Q(x_i) \leq Q(x_{i+1}) \forall x_i < x_{i+1}$, $Q(0) = 0$, $Q(1) = 1$ [14]

3) Sugeno integral based method: [13] is another method to evaluate quantified sentences which also requires coherent quantifiers. In the relative quantifier case, the evaluation is:

$$S_Q(A) = \max_{1 \leq i \leq n} \min\left(Q\left(\frac{P(A)}{|X|}\right)\right) \tag{3}$$

4) Delgado's GD method: [14] uses a fuzzy cardinality E.

The evaluation of a Type-1 description with relative quantifiers is as follows:

$$GD_Q(A) = \sum_{i=0}^{n} ED(A, i) \times Q\left(\frac{i}{n}\right) \tag{4}$$

where any t-norm and t-conorm can be used. In our evaluation, we selected the product t-norm and Łukasiewicz's t-conorm, which are the ones defined in [14].

On the other hand, $ED(A, k) = b_k - b_{k+1}$ with $b_0 = 1$ and $b_{n+1} = 0$ is a particular case of the E cardinality, using the minimum t-norm, Łukasiewicz's t-norm, the maximum t-conorm and the standard negation. Considering a set of $\alpha - cuts$ of A plus $\emptyset$, the possibility that a A_α is a subset of A is α and an integer k with $1 \leq k \leq n$ such that $\alpha = b_k$.

5) ZS method: This method [15] is based on Zadeh's fuzzy cardinality:

$$Z(A, k) = \begin{cases} 0 & \text{if } \nexists \alpha \mid |A_\alpha| = k, \\ sup\{\alpha \mid |A_\alpha| = k\} & otherwise \end{cases} \tag{5}$$

Its evaluation for relative quantifiers is:

$$ZS_Q = \max_{k \in \{0,\ldots,n\}} \min\left(Z(A, k), Q\left(\frac{k}{n}\right)\right) \tag{6}$$

B. Type-2 models

As indicated in the previous sections, Type-2 descriptions follow the "Q DX are A" protoform.

1) Zadeh's method: [11] defined (as in Type-1, for the minimum t-norm) as:

$$Z_Q(A/D) = Q\left(\frac{P(A \cap D)}{P(D)}\right) \tag{7}$$

where $P(A \cap D) = \sum_{i=1}^{n} A(x_i) \wedge D(x_i)$.

2) Yager's method based on OWA operators: [12] which can only be generalized to Type-2 sentences using coherent and relative quantifiers.

The evaluation is:

$$Y_Q(A/D) = \sum_{i=1}^{n} = w_i c_i \tag{8}$$

where w_i is a coefficient obtained between the quantifier and $|X|$ to ensure that the evaluation is coherent calculated as follows:

$$w_i = Q(S_i) - Q(S_{i-1}) \; i \in \{1, ..., n\} \tag{9}$$

and $S_0 = 0$ and c_i is the i-th high value of the $\neg D \vee A$ set's truth value.

3) Vila, Cubero, Medina and Pons' method: [16] uses the "or" or "orness" degree defined for coherent quantifiers. $orness(\exists) = 1$ and $orness(\forall) = 0$.

The evaluation for a Type-2 sentence is:

$$\begin{aligned} V_Q(A/D) = o_Q \max_{x \in X}(D(x) \wedge A(x)) \\ +(1 - o_Q) \min_{x \in X}(A(x) \vee (1 - D(x))) \end{aligned} \tag{10}$$

where o_Q is the orness degree. The definition on this method uses the minimum as t-norm and the maximum as t-conorm so we also selected this criteria in our evaluation.

4) Delgado's GD method: The generalization of this method [14] is defined as the compatibility between the ER cardinality and the quantifier by means of te product and the Łukasiewicz's t-conorm, as follows:

$$GD_Q(A/D) = \sum_{c \in CR(A/D)} ER(A/D, c) \times Q(c) \tag{11}$$

where

$$CR(A/D) = \{\frac{|(A \cap D)_\alpha|}{|D_\alpha|} \; with \; \alpha \; \in \; M(A/D)\} \tag{12}$$

and

$$\begin{aligned} M(A/D) = M(A \cap D) \cup M(D), \; and \\ M(A) = \{\alpha \in (0, 1] \; | \exists x_i \in X \; with \; A(x_i) = \alpha\} \end{aligned} \tag{13}$$

5) ZS method: [15], [19] uses the fuzzy cardinality ES, which consists in a max-min composition between such cardinality and the quantifier, and can be defined as:

$$ZS_Q(A/D) = \max_{\alpha \in M(A/D)} \min(\alpha, Q\left(\frac{|(A \cap D)_\alpha|}{|D_\alpha|}\right) \tag{14}$$

III. Materials and methods

A. Data set

As mentioned above, in this study we evaluate Type-1 and Type-2 quantified sentences from meteorological data. A meteorological situation is calculated by complex numerical models including a high number of variables and is usually represented with maps, which are often not intuitive due to the high amount of icons used for representing the different weather situations.

In our case, we used data from a real-time observation service for each Galician council provided by the Galician Meteorology Agency (MeteoGalicia). This service provides information for the following meteorological variables of interest: sky state, wind and temperature. Figure 1 shows a meteorological real example map for these three variables. Both the sky and wind icons are the standard ones used in MeteoGalicia whereas in the temperature maps the possible values are: VL (very low), L (low), N (normal), H (high), VH (very high). These are printed in different colors from red, associated to high temperatures, to dark blue, associated to low temperature values.

1) Sky state: This variable describes the state of the sky based on two variables: cloud coverage and rainfall. Meteorologists labeled the values of this variable with 42 integer codes used to describe the day (21 integer numbers in the range [101, 121]) and the night situations (21 integer numbers in the range [201, 221]). For example, 101 means *"clear sky"* whereas 211 means *"night with clear sky"*.

2) Wind: This variable that comprises the wind direction and speed, and is labeled with integer 34 codes in the range [299, 332]. Meteorologists consider eight wind directions (N, S, E, W, NW, NE, SE, SW) combined with four wind speed values (weak, moderate, strong, very strong). Also the calm and variable direction situations are considered. For instance, 305 code means "South direction and weak speed".

3) Temperature: Represents the temperature in degrees Celsius.

B. Linguistic descriptions

In this section, we present the definition of the linguistic variables we used in this study, based on the three meteorological variables previously described.

1) Sky: It is treated as a crisp variable, therefore the values of the meteorological variable are the values of the resulting linguistic variable. Each value in the meteorological variable is defined as a singleton having an integer code as label and a degree of truth in the set {0, 1}.

2) Wind: It is also a crisp variable, so the resulting linguistic variable has values in the range [299, 332] defined as singletons. Likewise, each value has a fulfillment degree in the set {0, 1}.

3) Temperature: This numerical variable represents the temperature in degrees Celsius. We modeled the linguistic variable as a fuzzy variable with the following five labels: {"very low", "low", "normal", "high", "very high"}, which are defined as fuzzy sets.

In order to provide meaning and contextualization for these labels, meteorologists define a reference temperature value. This reference is taken from the average temperature, $\bar{x}$, and its standard deviation, σ, for the last twenty years, for each location and each month of the year. These two values were used to model the labels presented in Figure 2. For instance, the label "normal" is defined with the trapezoid with support $[\bar{x} - \sigma, \bar{x} + \sigma]$ and core $[\bar{x} - 0.5\sigma, \bar{x} + 0.5\sigma]$. Thus, for a specific location with, for instance, $\bar{x} = 14.2$ and $\sigma = 4.8$, its "normal" label has support [9.4, 19] and core [11.8, 16.6].

4) Quantifiers: As we mentioned above, we generate quantified sentences (e.g. *"In most locations the wind has North direction and moderate speed"*). Therefore, quantifiers are necessary to count the number of elements in the referential that fulfills the condition.

We defined the five quantifiers ("at least 25%", "at least 50%", "at least 75%", "most", "all"), represented in Figure 3. All of them are modeled as coherent (as defined in Section II-A), since some quantification methods (Yager's method, Sugeno integral based method, and Vila et al. method) only support quantifiers that fulfill this property.

(a) Sky state (b) Wind (c) Temperature

Fig. 1: Real Map representing the meteorological state for the three variables of interest

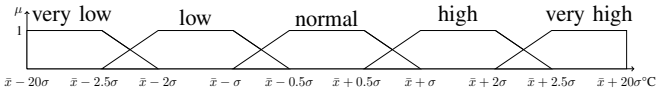


Fig. 2: Linguistic variable temperature definition.

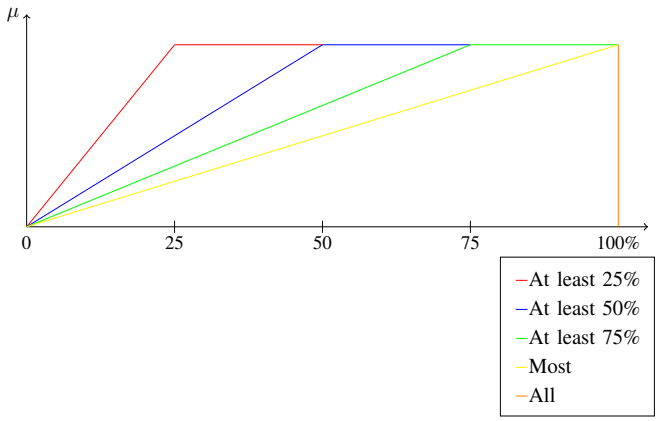


Fig. 3: Quantifiers definition for the percentage of locations.

5) Geographical descriptors: for Type-2 sentences we added a geographical qualifier. This allows us to describe smaller regions instead of the whole territory, which happens only in Type-1 descriptions. For instance, "In some locations in the North the temperature is low."

We defined nine linguistic geographical descriptors (N, S, E, W, Center, NE, NW, SE and SW), using longitude and latitude as reference as shown in Figure 4.

In the defined descriptors set, we can classify them into two subsets: simple or composite. A geographical descriptor is simple if only uses one dimension (latitude or longitude) in its definition, for instance "North" uses the latitude. On the contrary, a composite descriptor uses both dimensions, for example, "SW" uses both longitude and latitude.

With these components, we generated the quantified statements. In Type-1 descriptions (*"Q X are A"*) Q is the set of defined quantifiers, X is the set of described points and A is a combination of one or more of the linguistic variables created from the meteorological variables. For instance, "In some places the sky is clear and the temperature is high". Besides, in Type-2 K is the set of geographical descriptors previously defined. For example, "In most places in the North the sky is covered".

C. Experiments

The experimentation we performed in this study consisted mainly in two steps: *i)* generating the linguistic descriptions and *ii)* analyzing the quantification models behavior to evaluate their similarity. Figure 5 describes the performed stages in this experimentation and their corresponding inputs and outputs.

1) Linguistic descriptions generation: in the first stage, we generated all Type-1 and Type-2 descriptions from several real meteorological situations.

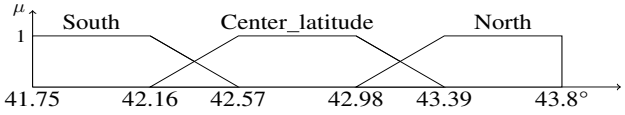
Firstly, we collected data from 15 different days and times of the day from 30th July 2019 to 30th August 2019. Thus, we ensured having a wide variety of situations, all independent from each other.

We generated all possible descriptions from this resulting data set, obtaining for each meteorological situation 45,145 Type-1 descriptions and 406,305 Type-2 descriptions.

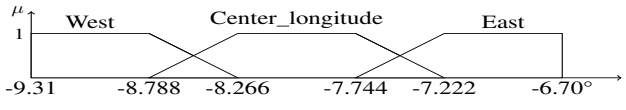
For each generated sentence, we assessed how descriptive it was in terms of the meteorological situation described by the data. Thus, at this stage, we evaluated the descriptions with the selected quantification methods.

2) Quantification methods correlation comparison: We performed correlation coefficient tests in order to determine whether the quantification models have similar behaviors when evaluating quantified descriptions.

Among the different correlation tests, we selected the Pearson test, which is applied over the degree of truth, giving information about the similarity of quantification methods results, instead of ranking the descriptions based on the associated truth value. We performed this test in two stages: *i)* the test was performed over the data set from 30th July 2019 and *ii)* test was performed for each description over the average of evaluation result of the 15 data sets. Besides, in this second stage we performed two separate tests: *i)* applying the correlation coefficient test only to those quantified sentences which described the temperature and *ii)* applying test to quantified sentences which describe the three meteorological variables (temperature, sky state and wind). Sky state and wind values were filtered in order to only generate descriptions that



(a) Latitude definition.



(b) Longitude definition.

Fig. 4: Geographical descriptors definition.

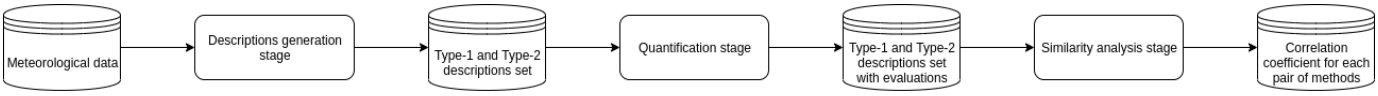


Fig. 5: Description of the experimentation stages with their inputs and outputs.

described actual situations in the data sets. So descriptions were generated with 5 different sky states (101, 103, 104, 105 and 111) and with 18 different wind states (from 300 to 316 and 318).

IV. Experimental results

In this section, we present the obtained results applying the Pearson correlation test to the different sets of descriptions for Type-1 and Type-2 descriptions.

A. Type-1 descriptions

1) 30 July 2019 results: results of the Pearson correlation coefficient with the 30 July 2019 data set (Table I) confirm there is a very high correlation between the quantification methods, with correlations higher than 0.9. A total correlation is obtained between the pairs Y_Q - GD_Q and S_Q - ZS_Q, which is consistent with [14], where it is stated that these methods coincide for coherent quantifiers.

	Z_Q	Y_Q	S_Q	GD_Q	ZS_Q
Z_Q	1	0.9995	0.9925	0.9995	0.9925
Y_Q		1	0.9945	1	0.9945
S_Q			1	0.9945	1
GD_Q				1	0.9945
ZS_Q					1

TABLE I: Pearson correlation coefficient for quantification methods evaluating Type-1 descriptions from 30 July 2019.

2) Average results describing only temperature: in Table II we present the results of the Pearson test with the resulting average data set describing only the temperature situation.

Also in this case, the correlation coefficient between all quantification methods pairs is very high and the total correlation between the pairs Y_Q - GD_Q and S_Q - ZS_Q was also obtained.

3) Average results including all meteorological variables: table III shows the correlations in this experiment. This experiment also confirms the conclusions of the previous tests. Therefore, there are not significant differences between the quantification methods when evaluating Type-1 quantified descriptions.

Analyzing these three different tests results, we can conclude when evaluating Type-1 descriptions the compared methods do not show differences between their behaviors since

	Z_Q	Y_Q	S_Q	GD_Q	ZS_Q
Z_Q	1	0.9983	0.9987	0.9998	0.9987
Y_Q		1	0.9992	1	0.9992
S_Q			1	0.9992	1
GD_Q				1	0.9992
ZS_Q					1

TABLE II: Pearson correlation coefficient for quantification methods evaluating Type-1 descriptions from the average data set describing temperature.

	Z_Q	Y_Q	V_Q	GD_Q	ZS_Q
Z_Q	1	0.9999	0.9976	0.9999	0.9976
Y_Q		1	0.9979	1	0.9979
S_Q			1	0.9979	1
GD_Q				1	0.9979
ZS_Q					1

TABLE III: Pearson correlation coefficient for quantification methods evaluating Type-1 descriptions from the average data set including all meteorological variables.

their correlation coefficient is higher than 0.9 between all models pairs. This is consistent with the analysis of properties described in [19] for Type-1 evaluation. We compile in Table IV a summary of the most relevant properties, where it can be seen that all methods fulfill the six properties considered, with the only exceptions of Z_Q (which does not fulfill properties 4 and 6) and Y_Q, which does not fulfill property 7.

Furthermore, the method pairs GD_Q - Y_Q and ZS_Q - S_Q had a correlation coefficient of 1, which are consistent with the theoretical previous work [14] when it is proved these pair of methods are equivalent with coherent quantifiers.

B. Type-2 descriptions

1) 30 July 2019 results: Results of the Pearson correlation coefficient (Table V) of the compared quantification models when evaluating Type-2 quantified descriptions show a high correlation between the methods Z_Q, GD_Q and ZS_Q. However, the correlation between V_Q with the others is lower than 0.85. Also Y_Q has low correlation coefficient when comparing its behavior with the other four methods.

2) Average results describing only temperature: results presented in Table VI, show high correlation between Z_Q, GD_Q, V_Q and ZS_Q. Also in this case, Y_Q have lower correlation with the others methods than when evaluating Type-1 descriptions.

Property	Description	Encoding as in [19]	Z_Q	Y_Q	GD_Q	S_Q	V_Q	ZS_Q
1	Absolute-relative transformation and correct generalization	I.1	✓	✓	✓	✓	NA	✓
2	Quantifiers monotonicity	I.3	✓	✓	✓	✓	NA	✓
3	Correct generalization	II.1	✓	✓	✓	NA	✓	✓
4	Coherence with fuzzy logic	I.2	X	✓	✓	✓	NA	✓
		II.6 (∃)	NI	X	✓	NA	✓	✓
		II.6 (∀)	NI	✓	X	NA	✓	✓
5	Computational complexity	I.4	O(n)	O(n log n)	O(n log n)	O(n log n)	NA	O(n log n)
		II.3	O(n)	O(n log n)	O(n log n)	NA	O(n)	O(n log n)
6	Not too strict evaluation	I.5	X	✓	✓	✓	NA	✓
		II.8	NI	✓	✓	NA	NI	✓
7	Valid for any quantifiers	I.6	✓	X	✓	✓	NA	✓
		II.7	✓	NI	✓	NA	✓	✓
8	Type-2 to Type-1 transformation	II.2	NI	NI	✓	NA	NI	✓
9	If D is a normal fuzzy set and $D \subseteq A$ the evaluation is 1	II.4	✓	NI	✓	NA	NI	✓
10	If $D \cap A = \emptyset$, the evaluation is 0	II.5	✓	X	✓	NA	NI	✓

TABLE IV: Recompilation of the properties analyzed in [19] with the corresponding encoding for Type-1 (I.x) and Type-2 (II.x) evaluations (as in [19], NI means no information is available and NA means property does not apply).

	Z_Q	Y_Q	V_Q	GD_Q	ZS_Q
Z_Q	1	0.3899	0.7610	0.9862	0.9396
Y_Q		1	0.3330	0.3811	0.3825
V_Q			1	0.7727	0.8338
GD_Q				1	0.9595
ZS_Q					1

TABLE V: Pearson correlation coefficient for quantification methods evaluating Type-1 descriptions from the 30 July 2019 data set describing temperature.

	Z_Q	Y_Q	V_Q	GD_Q	ZS_Q
Z_Q	1	0.7716	0.9694	0.9870	0.9806
Y_Q		1	0.7711	0.7508	0.7514
V_Q			1	0.9834	0.9850
GD_Q				1	0.9935
ZS_Q					1

TABLE VI: Pearson correlation coefficient for quantification methods evaluating Type-2 descriptions from the average data set describing temperature.

3) Average results including all meteorological variables: these experiments, as the performed with the 30 July 2019 data set, show a high correlation between Z_Q, GD_Q and ZS_Q whereas V_Q and Y_Q have lower correlation with the others. Results are presented in Table VII.

	Z_Q	Y_Q	V_Q	GD_Q	ZS_Q
Z_Q	1	0.2686	0.8168	0.9926	0.9759
Y_Q		1	0.2875	0.2547	0.2754
V_Q			1	0.8256	0.8703
GD_Q				1	0.9831
ZS_Q					1

TABLE VII: Pearson correlation coefficient for quantification methods evaluating Type-2 descriptions from the average data set including all meteorological variables.

The results of this tests set show lower correlation between the analyzed models in comparison with the Type-1 case. Besides, results show V_Q and Y_Q have low correlations with the compared methods whereas Z_Q, GD_Q and ZS_Q have a similar behavior. One possible explanation for the correlation between Z_Q and GD_Q is their type, since both models are sum-based methods. On the other hand, the correlated behavior between GD_Q and ZS_Q can be explained by their cardinality type, since both of them are based on fuzzy cardinalities.

Regarding the Type-2 properties described in Table IV, the three fuzzy quantification models share properties 7, 9 and 10. Besides, GD_Q and ZS_Q also fulfill properties 4 (∃) (ZS_Q also fulfills property 4 (∀)), 6 and 8 whereas Z_Q and ZS_Q share property 3.

Regarding Y_Q, this model is the only one which does not fulfill properties 4 (∃) and 10. This non-compliance could explain the low correlation between this method and the other four quantification methods.

On the other hand, V_Q fulfills properties 3, 4 (∃), 4 (∀) and 7. Therefore, the correlation between this method and Z_Q, GD_Q and ZS_Q could be explained by these shared properties.

V. Conclusions

In this paper, we presented an experimental study to compare the behavior of six well-known quantification methods when evaluating Type-1 and Type-2 quantified descriptions.

We performed our experiments using meteorological data provided by the Galician Meteorology Agency. Three different tests were performed both for Type-1 and Type-2 descriptions.

Test results show there are no significant differences between the behavior of the quantification models when evaluating Type-1 descriptions. Besides, our results are consistent with the theoretical results that state that GD_Q [14] and [12] methods, on one hand, and [15] and [13] methods, on the other, coincide for coherent quantifiers, since for these two pairs we obtained a correlation coefficient of 1.The results also prove a very similar behavior between all pairs of methods, with a correlation coefficient higher than 0.9 in all cases.

In the Type-2 scenario, correlation between the quantification models is lower than for Type-1, but methods can be clustered into three categories according to their correlation: *i)* Z_Q, GD_Q and ZS_Q, *ii)* V_Q and *iii)* Y_Q.

As future work, we are extending our experimentation in the Type-2 scenario in different ways: *i)* increasing the number of data sets in order to confirm whether the correlation between the quantification methods is independent of the data; *ii)* considering other definitions or partitions of quantifiers and other criteria if possible; and *iii)* extending the current

experimentation including new quantification methods and extending the study of their properties and results to verify if their similarities are by chance or not.

ACKNOWLEDGMENTS

This research was funded by the Spanish Ministry for Science, Innovation and Universities (grants TIN2017-84796-C2-1-R and TIN2017-90773-REDT) and the Galician Ministry of Education, University and Professional Training (grants ED431C 2018/29, "accreditation 2016-2019, ED431G/08" and ED431G2019/04). All grants were co-funded by the European Regional Development Fund (ERDF/FEDER program).

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