BOOK OF ABSTRACTS

17th International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems – IPMU 2018

Cádiz, Spain, June 11th – 15th, 2018

Editors

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Preface

It is a great pleasure to welcome you to the ***17th International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems*** (IPMU 2018), which will be held at Cádiz, from June 11th to 15th, 2018, in the *Edificio Constitución 1812* (previous *Aulario La Bomba*), and is being locally organized by the team headed by Dr. Jesús Medina, Full Professor of Applied Mathematics of the University of Cádiz.

This book contains the program of IPMU2018, maps of the two buildings in which the conference will be held - *Facultad de Filosofía y Letras* (for the plenary talks and the Round Table: Homage Lotfi A. ZadehI and *Edificio Constitución 1812* (for the rest of activities) - and the abstracts of the accepted papers of this important international conference, which have already been published in

- Jesús Medina, Manuel Ojeda-Aciego, José Luis Verdegay Galdeano, David A. Pelta, Inma P. Cabrera, Bernadette Bouchon-Meunier, Ronald R. Yager:
  Information Processing and Management of Uncertainty in Knowledge-Based Systems. Theory and Foundations Parts I and II. Communications in Computer and Information Science 853 and 854, Springer 2018.

- Jesús Medina, Manuel Ojeda-Aciego, José Luis Verdegay Galdeano, Irina Perfilieva, Bernadette Bouchon-Meunier, Ronald R. Yager:
  Information Processing and Management of Uncertainty in Knowledge-Based Systems. Applications, Part III, Communications in Computer and Information Science 855, Springer 2018.

A notable margin has been provided in each page with the philosophy that you can take notes in an easy way next to the data of the paper. Additionally, at the end of the book you can find different white pages for writing more detailed comments.

We would also like to note that this event is one of the most important conferences in the area of Mathematics and Computer Science, in which more than 300 participants, from more than 40 countries of the five continents, together with the most important researchers in the areas related to the uncertainty in knowledge-based systems, will present their latest advances and achievements. These contributions will provide a wonderful atmosphere in order to create and continue successful collaborations and synergies for developing future international projects.

Furthermore, in this edition, a well-deserved homage will be paid to the father of the fuzzy logic and co-founder of the IPMU, Dr. Lotfi A. Zadeh, who passed away on September 6th, 2017. The following special activities have been scheduled, among others:

– A special panel session on the legacy of Lotfi Zadeh, in which panellists will speak of the scientific and application legacy of Lotfi Zadeh's ideas.

– The creation of the Lotfi A. Zadeh IPMU best paper award.

– A photo book illustrating the Lotfi A. Zadeh continued close relationship with IPMU participants.

The panel will be composed of Ronald R. Yager (Iona College, New York, USA), Bernadette Bouchon-Meunier (University Pierre et Marie Curie, France), Didier Dubois (IRIT, Toulouse, France), Janusz Kacprzyk (Polish Academy of Sciences, Warsaw, Poland), Rudolf Kruse (University of Magdeburg, Germany), and Luis Magdalena (Universidad Politécnica de Madrid, Spain).

Dr. Lotfi A. Zadeh was also the first winner of the prestigious Kampé de Fériet Award in 1992. The IPMU2018 Kampé de Fériet Award has been given to Glenn Shafer (Rutgers University, Newark, United States) for his seminal contributions to the mathematical theory of evidence and belief functions as well as to the field of reasoning under uncertainty. The so-called Dempster-Shafer theory, an alternative to the theory of probability, has been widely applied in engineering and artificial intelligence.

Additionally, besides being grateful for the talk which will be given by Professor Glenn Shafer after the welcome reception, we want to give thanks to the five excellent keynote speakers for their lectures: Yiyu Yao (University of Regina, Canada) and Enrique Herrera-Viedma (University of Granada, Spain) on Tuesday 12th, Lluis Godo (IIIA-CSIC, Barcelona, Spain) on Wednesday 13th, Gloria Bordogna (IREA-CNR, France) on Thursday 14th, and Natalio Krasnogor (Newcastle University, UK) on Friday 15th. We are also very grateful with the contribution of the special session organizers, scientific committee members and reviewers, who have played a very important part in making IPMU 2018 a success. We would like to thank the participants because, without their interest and enthusiasm, the conference would not have been possible. We also acknowledge the support received from different areas of the University of Cádiz, such as the Department of Mathematics, the PhD program in Mathematics, the Vice-rectorate of Infrastructures and Patrimony, and the Vice-rectorate for Research; the International Global Campus of Excellence of the Sea (CEI·Mar) led by the University of Cádiz and composed of institutions of three different countries; the European Society for Fuzzy Logic and Technology (EUSFLAT) and the Springer team who managed the proceedings edition. Finally, the organizing committee acknowledges the support of the research project TIN2016-76653-P (Spanish Ministery of Economy and Competitiveness, including FEDER funds).

Thus, the University of Cádiz will be from June 11th to 15th the centre of the new technologies focused on information processing and management of uncertainty in knowledge-based systems, where the most recent advances will be presented and new future challenges will be designed in these areas.

The official webpage of IPMU2018: http://ipmu2018.uca.es/ can be consulted for more information.

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Cádiz, Spain, June 2018

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	Monday 11th.			
8:30 - 9:30	**Registration desk open. Facultad de Filosofía y Letras**			
9:30 - 10:00	**Welcome**			
10:30 - 11:30	**Plenary talk: Prof. Glenn Shafer**			
11:00 - 11:30	Coffee break			
8:30 - 9:30	**S.11.B.1**	**S.11.B.2**	**S.11.B.3**	**S.11.B.4**
	SS.2. Aggregation Operators, Fuzzy Metrics and Applications (I)	SS.7. Formal Concept Analysis and Uncertainty	SS.11. Fuzzy methods in Data Mining and Knowledge Discovery (I)	General Track
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16:50 - 18:20	**S.11.C.1**	**S.11.C.2**	**S.11.C.3**	**S.11.C.4**
	SS.2 Aggregation Operators, Fuzzy Metrics and Applications (II)	SS28. Tri-partitions and uncertainty	SS.11. Fuzzy methods in Data Mining and Knowledge Discovery (II)	SS.29. Uncertainty in medicine
20:00	Welcome reception			

Session Room	Room	Floor	Building
Plenary S.	Salón de Actos -Aulta Magna	Second floor	Facultad de Filosofía y Letras
S.XX.Y.1	Sala Lequerica	Ground floor	Edificio Constitución 1812
S.XX.Y.2	Sala Bolívar	First floor	Edificio Constitución 1812
S.XX.Y.3	Sala Argüelles	First floor	Edificio Constitución 1812
S.XX.Y.4	Aula 2	Ground floor	Edificio Constitución 1812

	Tuesday 12th.				
8:30	**Registration desk open. Edificio Constitución 1812**				
9:00 - 10:00	**Plenary talk: Prof. Yiyu Yao**				
10:00 - 11:00	**S.12.A.1**	**S.12.A.2**	**S.12.A.3**	**S.12.A.4**	
	SS.4. Current techniques to model, process and describe time series	SS.25. Rough and Fuzzy Similarity Modelling Tools (I)	SS.5. Decision Making modeling and applications (I)	SS.2 Aggregation Operators, Fuzzy Metrics and Applications (III)	
11:00 - 11:30	Coffee break				
11:30 - 13:30	**S.12.B.1**	**S.12.B.2**	**S.12.B.3**	**S.12.B.4**	**S.12.B.5**
	SS.27. Soft Computing in Information Retrieval and Sentiment Analysis	SS.25. Rough and Fuzzy Similarity Modelling Tools (II)	SS.5. Decision Making modeling and applications (II)	SS.21. New trends in data aggregation	SS.9. Fuzzy Logic and Artificial Intelligence Problems (I)
13:30 - 15:00	Lunch				
15:00 - 16:00	**Plenary talk: Prof. Enrique Herrera-Viedma**				
16:00 - 16:30	Coffee break				
16:30 - 18:00	**S.12.C.1**	**S.12.C.2**	**S.12.C.3**		
	SS.23. Pre-aggregation functions and generalized forms of monotonicity	SS.9. Fuzzy Logic and Artificial Intelligence Problems (II)	SS.5. Decision Making modeling and applications (III)		
18:00 - 20:00	EUSFLAT Meeting				

Session Room	Room	Floor	Building
Plenary S.	Salón de Actos -Aulta Magna	Second floor	Facultad de Filosofía y Letras
S.XX.Y.1	Sala Lequerica	Ground floor	Edificio Constitución 1812
S.XX.Y.2	Sala Bolívar	First floor	Edificio Constitución 1812
S.XX.Y.3	Sala Argüelles	First floor	Edificio Constitución 1812
S.XX.Y.4	Aula 2	Ground floor	Edificio Constitución 1812
S.XX.Y.5	Aula 8	Second floor	Edificio Constitución 1812

	Wednesday 13th.			
8:30	**Registration desk open. Edificio Constitución 1812**			
9:00 - 10:00	**Plenary talk: Prof. Lluis Godo**			
10:00 - 11:00	**S.13.A.1**	**S.13.A.2**	**S.13.A.3**	**S.13.A.4**
	General track	General track	General track	SS.22. Optimization models for modern analytics (I)
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11:30 - 13:40	**S.13.B.1**	**S.13.B.2**	**S.13.B.3**	**S.13.B.4**
	SS.1. Advances on Explainable Artificial Intelligence	SS.17. Mathematical Fuzzy Logic	SS.13. Imprecise Probabilities: foundations and applications	SS.22. Optimization models for modern analytics (II)
13:40 - 15:00	Lunch			
16:30 - 19:00	Social event			
20:00	Gala dinner			

Session Room	Room	Floor	Building
Plenary S.	Salón de Actos -Aulta Magna	Second floor	Facultad de Filosofía y Letras
S.XX.Y.1	Sala Lequerica	Ground floor	Edificio Constitución 1812
S.XX.Y.2	Sala Bolívar	First floor	Edificio Constitución 1812
S.XX.Y.3	Sala Argüelles	First floor	Edificio Constitución 1812
S.XX.Y.4	Aula 2	Ground floor	Edificio Constitución 1812

	Thursday 14th.			
9:30	**Registration desk open. Edificio Constitución 1812**			
10:00 - 11:00	**Plenary talk: Prof. Gloria Bordogna**			
11:00 - 11:30	Coffee break			
11:30 - 13:30	**S.14.B.1**	**S.14.B.2**	**S.14.B.3**	**S.14.B.4**
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13:30 - 15:00	Lunch			
15:00 - 16:00	**Round table. ICTs and CEI·MAR**			
16:00 - 16:30	Coffee break			
16:30 - 18:00	**S.14.C.1**	**S.14.C.2**	**S.14.C.3**	
	SS.6. Discrete models and Computational Intelligence	SS.14. Logical methods in mining knowledge from big data	General track	

Session Room	Room	Floor	Building
Plenary S.	Salón de Actos -Aulta Magna	First floor	Facultad de Filosofía y Letras
S.XX.Y.1 and Round Table	Sala Lequerica	Ground floor	Edificio Constitución 1812
S.XX.Y.2	Sala Bolívar	First floor	Edificio Constitución 1812
S.XX.Y.3	Sala Argüelles	First floor	Edificio Constitución 1812
S.XX.Y.4	Aula 2	Ground floor	Edificio Constitución 1812

	Friday 15th.			
8:30	**Registration desk open**			
9:00 - 10:00	**Plenary talk: Prof. Natalio Krasnogor**			
10:00 - 11:00	**S.15.A.1**	**S.15.A.2**	**S.15.A.3**	**S.15.A.4**
	SS.12. Fuzzy transforms: theory and applications to data analysis and processing (I)	SS.26. Soft Computing for Decision Making in Uncertainty (I)	General track	SS.20. Metaheuristics and Machine Learning (I)
11:00 - 11:30	Coffee break			
11:30 - 13:30	**S.15.B.1**	**S.15.B.2**	**S.15.B.3**	**S.15.B.4**
	SS.12. Fuzzy transforms: theory and applications to data analysis and processing (II)	SS.26. Soft Computing for Decision Making in Uncertainty (II)	SS.19. Measures of comparison and entropies for fuzzy sets and their extensions	SS.20. Metaheuristics and Machine Learning (II)
13:30	Closing session			

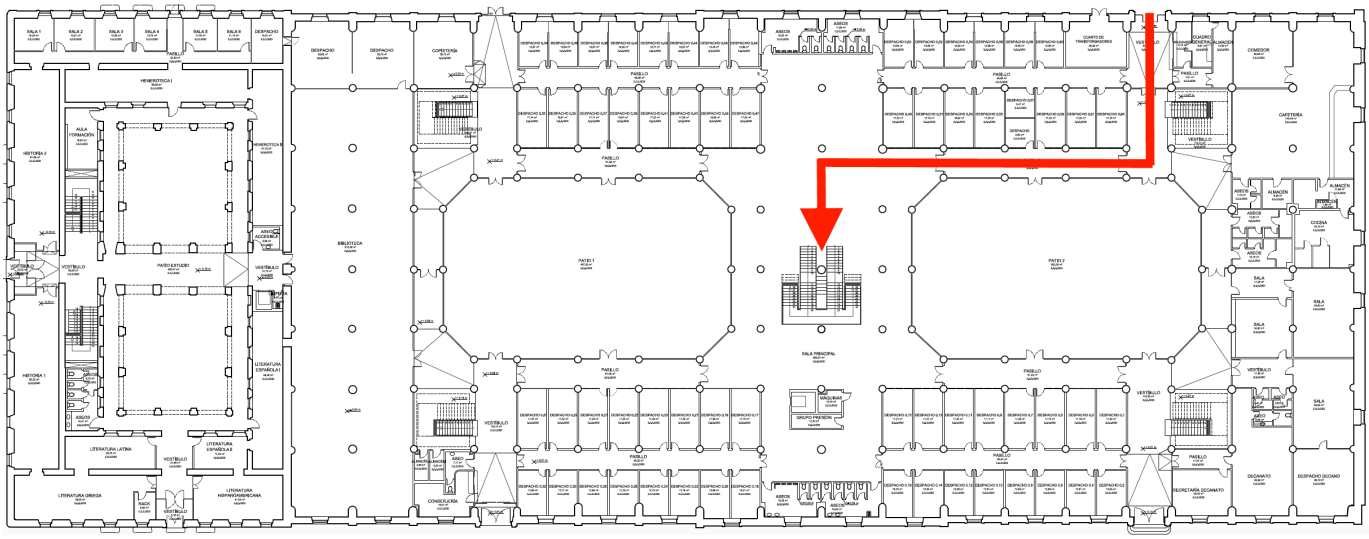
Session Room	Room	Floor	Building
Plenary S.	Salón de Actos -Aulta Magna	Second floor	Edificio Constitución 1812
S.XX.Y.1	Sala Lequerica	Ground floor	Edificio Constitución 1812
S.XX.Y.2	Sala Bolívar	First floor	Edificio Constitución 1812
S.XX.Y.3	Sala Argüelles	First floor	Edificio Constitución 1812
S.XX.Y.4	Aula 2	Ground floor	Edificio Constitución 1812


Punta Candelaria
Baluarte de la Candelaria
Centro Cultural Reina Sofía
Aparcamiento Santa Bárbara
Aulario "La Bomba" (Edificio 1812)
Calle Carmen Coronada
Jardines de Alameda Apodaca
3 min
210 m
Parque Genovés
Facultad de Filosofía y Letras
Plaza Mentidero
Calle Enrique de las Marinas
Plaza de la Oca
La Curiosidad de Mauro Barreiro
Av. Dr. Gómez Ulla
Calle San Dimas
Calle Navas
Plaza de San Antonio
Universidad de Cádiz
Casa de las Viudas
Parking El Tenis
Calle Zaragoza
Calle San Pedro

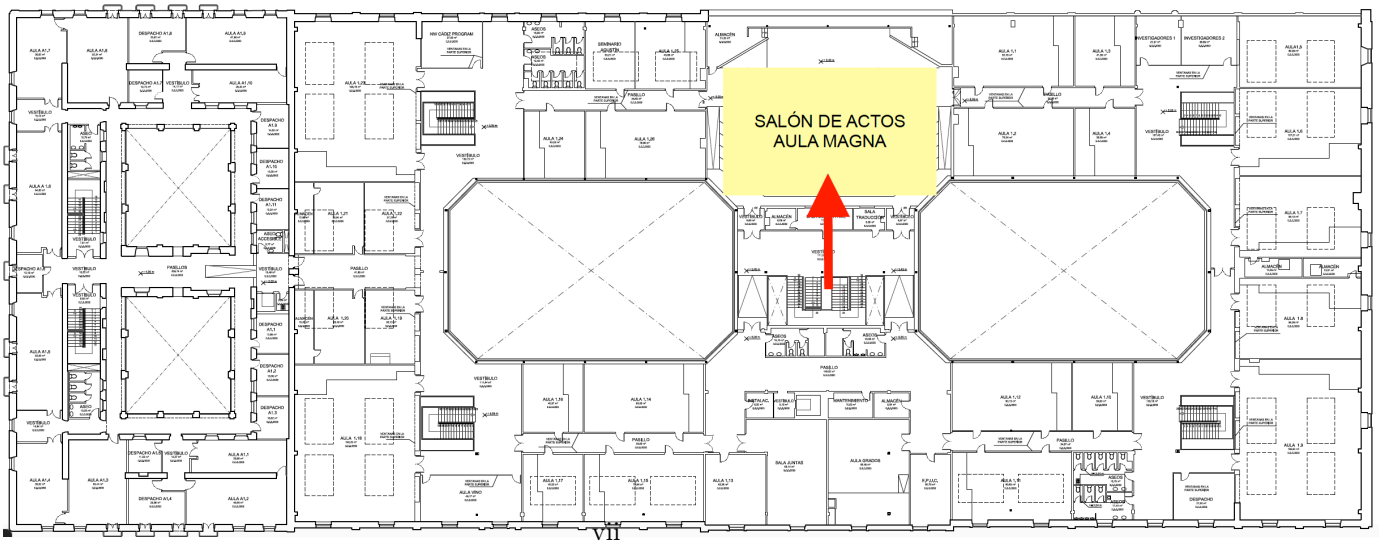
FACULTAD DE FILOSOFÍA Y LETRAS

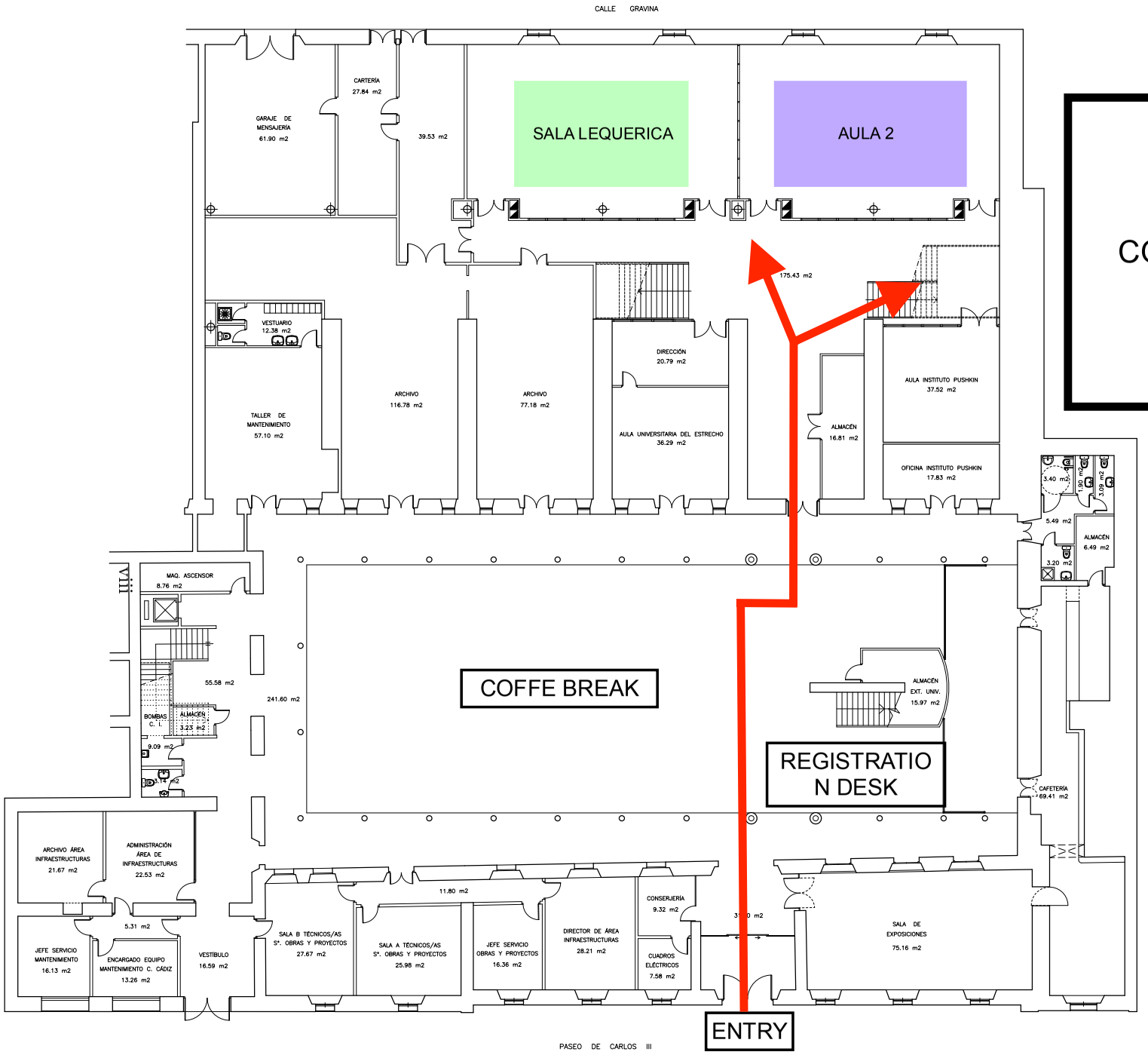
GROUND FLOOR

ENTRY



FIRST FLOOR





EDIFICIO CONSTITUCIÓN 1812 GROUND FLOOR

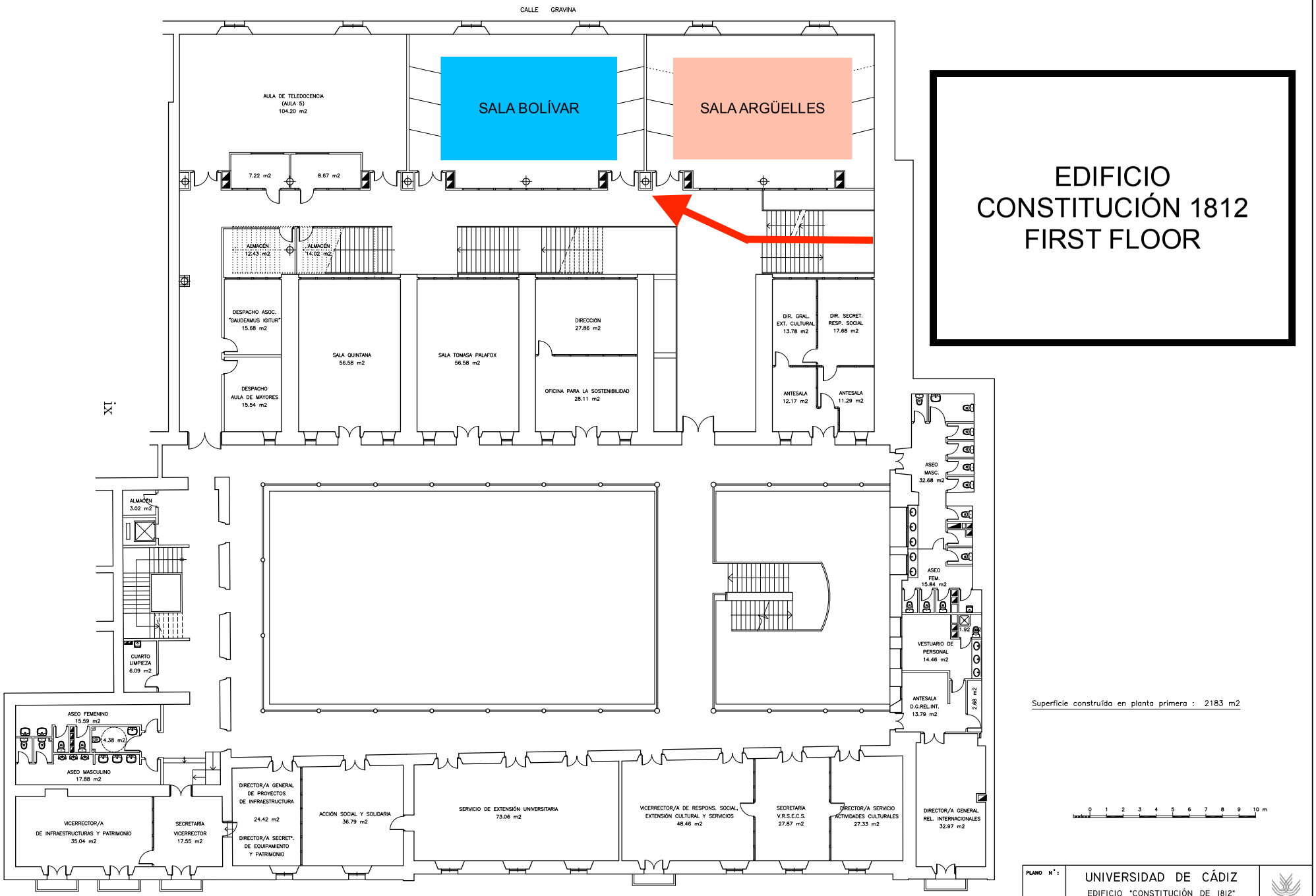
Superficie construída en planta baja : 2615 m2

Superficie total de la parcela : 2615 m2

0 1 2 3 4 5 6 7 8 9 10 m

PLANO Nº:	UNIVERSIDAD DE CÁDIZ EDIFICIO "CONSTITUCIÓN DE 1812"	
	PLANTA BAJA	ESCALA 1:100
ÁREA DE INFRAESTRUCTURAS SERVICIO DE OBRAS Y PROYECTOS		DIBUJADO: 05-2013

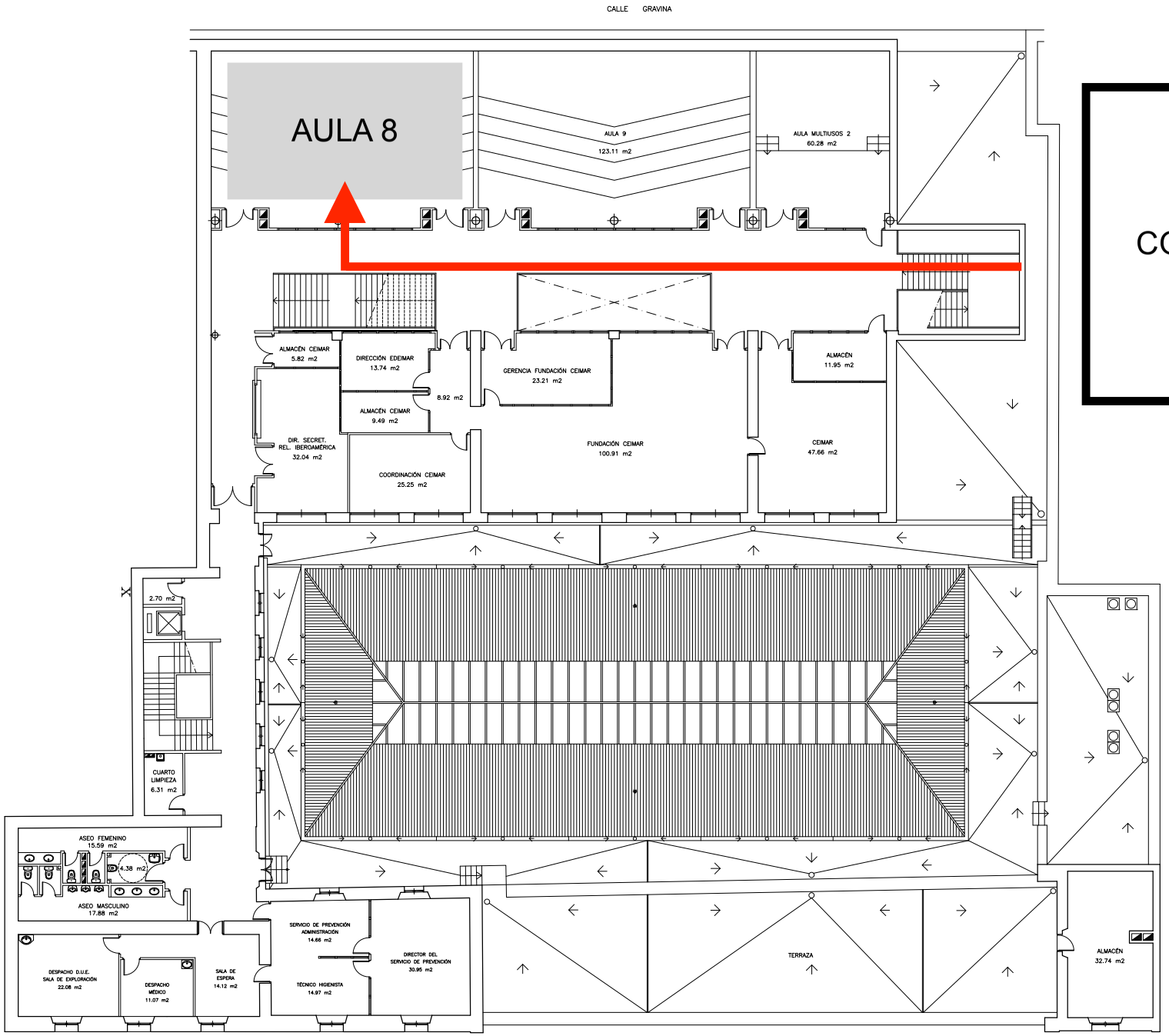
UCA Universidad de Cádiz



EDIFICIO CONSTITUCIÓN 1812 FIRST FLOOR

Superficie construída en planta primera : 2183 m2

PLANO N°:	UNIVERSIDAD DE CÁDIZ EDIFICIO "CONSTITUCIÓN DE 1812"	
	PLANTA PRIMERA	ESCALA 1:100
ÁREA DE INFRAESTRUCTURAS SERVICIO DE OBRAS Y PROYECTOS		DIBUJADO: 05-2013



EDIFICIO CONSTITUCIÓN 1812 SECOND FLOOR

Superficie construída en planta segunda : 1325 m2

0 1 2 3 4 5 6 7 8 9 10 m

PLANO Nº:	UNIVERSIDAD DE CÁDIZ EDIFICIO "CONSTITUCIÓN DE 1812"	
	PLANTA SEGUNDA	ESCALA 1:100
ÁREA DE INFRAESTRUCTURAS SERVICIO DE OBRAS Y PROYECTOS		DIBUJADO: 09-2015

UCA Universidad de Cádiz

17th International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems – IPMU 2018

Cádiz, Spain, June 11th – 15th, 2018

MONDAY 11th

M. 8:30–9:30 Registration desk open

M. 9:30–10:00 Welcome

M. 10:00-11:00 **Plenary talk: Hypothesis Testing as a Game**
Speaker: Prof. Glenn Shafer
Chairperson: Prof. Ronald R. Yager

M. 11:00-11:30 Coffee Break

M. 11:30-13:30 **Session 11.B.1: SS.2 Aggregation Operators, Fuzzy Metrics and Applications I**
Chairperson: Tomasa Calvo

Efficient Binary Fuzzy Measure Representation and Choquet Integral Learning.
Muhammad Aminul Islam, Derek Anderson, Xiaoxiao Du, Tomothy Havens and Christian Wagner.

Mortality Rates Smoothing Using Mixture Function.
Samuel Hudec and Jana Špirková.

Nullnorms and t-operators on bounded lattices: coincidence and differences.
Slavka Bodjanova and Martin Kalina.

On the use of fuzzy preorders in multi-robot task allocation problem.
José Guerrero, Juan-José Miñana and Óscar Valero.

On the problem of aggregation of partial T-indistinguishability operators.
Tomasa Calvo Sánchez, Pilar Fuster-Parra and Óscar Valero.

M. 11:30-13:30 **Session 11.B.2: SS.7. Formal Concept Analysis and Uncertainty**
Chairperson: Pablo J. Cordero

Study of the relevance of objects and attributes of L-fuzzy contexts using overlap indexes.
Cristina Alcalde and Ana Burusco.

FCA attribute reduction in information systems.
María José Benítez-Caballero, Jesús Medina and Eloísa Ramírez-Poussa.

Formal Concept Analysis and structures underlying Quantum Logics.
Ondrej Krídlo and Manuel Ojeda-Aciego.

Directness in Fuzzy Formal Concept Analysis.
Pablo Cordero, Manuel Enciso and Ángel Mora.

Formal independence analysis.
Francisco José Valverde Albacete, Carmen Peláez Moreno, Inma P. Cabrera, Pablo Cordero and Manuel Ojeda-Aciego

Spatio-temporal Drought Identification through Mathematical Morphology.
Hilde Vernieuwe, Bernard De Baets and Niko Verhoest.

M. 11:30-13:30 **Session 11.B.3: SS.11. Fuzzy methods in Data Mining and Knowledge Discovery I**
Chairperson: M. Dolores Ruiz

Fuzzy Analysis of Sentiment Terms for Topic Detection Process in Social Networks.
Karel Gutiérrez-Batista, Jesús R. Campaña, María-Amparo Vila and María J. Martin-Bautista.

Fuzzy association rules mining using Spark.
Carlos Fernández-Basso, M. Dolores Ruiz and María J. Martin-Bautista.

A Typology of Data Anomalies.
Ralph Foorthuis.

Two-sample dispersion tests for interval-valued data.
Przemyslaw Grzegorzewski.

IF-CLARANS: Intuitionistic fuzzy Algorithm for Big data clustering.
Hechmi Shili and Lotfi Ben Romdhane.

Semi-supervised fuzzy c-means variants: a study on noisy label supervision.
Violaine Antoine and Nicolas Labroche.

M. 11:30-13:30 **Session 11.B.4: General Track**
Chairperson: Martin Stepnicka

Singular Outliers: Finding Common Observations with an Uncommon Feature.
Mark Pijnenburg and Wojtek Kowalczyk.

Operational Measurement of Data Quality.
Antoon Bronselaer, Joachim Nielandt, Toon Boeckling and Guy De Tré.

Randomness of Data Quality Artifacts.
Toon Boeckling, Antoon Bronselaer and Guy De Tré.

Tag-based User Fuzzy Fingerprints for Recommender Systems.
André Carvalho, Pável Calado and Joao Paulo Carvalho.

M. 13:30-15:00 Lunch

M. 15:00-16:30 **Round Table: Homage Lotfi A. Zadeh**

Chairperson: Ronald Yager
Panelists: Bernadette Bouchon-Meunier, Didier Dubois, Janusz Kacprzyk, Rudolf Kruse, Rudolf Seising, Luis Magdalena.

M. 16:30-16:50 Coffee Break

M. 16:50-18:20 **Session 11.C.1: SS.2 Aggregation Operators, Fuzzy Metrics and Applications II**
Chairperson: Tomasa Calvo

What is the aggregation of a partial metric and a quasi-metric?
Juan-José Miñana and Óscar Valero.

Generalized Farlie-Gumbel-Morgenstern copulas.
Anna Kolesárová, Radko Mesiar and Susanne Saminger-Platz

Metrics for tag cloud evaluation.
Úrsula Torres Parejo, Jesús R. Campaña, Maria-Amparo Vila and Miguel Delgado.

Uninorms that are neither conjunctive nor disjunctive on bounded lattices.
Gül Deniz Çaylı.

M. 16:50-18:20 **Session 11.C.2: SS.28. Tri-partitions and uncertainty**
Chairpersons: Davide Ciucci and Yiyu Yao

An Efficient Gradual Three-way Decision Cluster Ensemble Approach.
Hong Yu and Guoyin Wang.

Modes of Sequential Three-Way Classifications.
Yiyu Yao, Mengjun Hu and Xiaofei Deng.
Determining Strategies in Game-theoretic Shadowed Sets.
Yan Zhang and JingTao Yao.

Three-way and Semi-Supervised Decision Tree Learning Based on Orthopartitions.
Andrea Campagner and Davide Ciucci.

M. 16:50-18:20 **Session 11.C.3: SS.11. Fuzzy methods in Data Mining and Knowledge Discovery II**
Chairperson: M. Dolores Ruiz

Towards an App based on FIWARE Architecture and Data Mining with Imperfect Data.
José M. Cadenas, M. Carmen Garrido and Cristina Villa.

A Fuzzy Close Algorithm for Mining Fuzzy Association Rules.
Régis Pierrard, Jean-Philippe Poli and Céline Hudelot.

A 2D-approach towards the Detection of Distress using Fuzzy K-Nearest Neighbor.
Daniel Machanje, Joseph Orero and Christophe Marsala.

Datil: Learning Fuzzy Ontology Datatypes.
Ignacio Huitzil, Umberto Straccia, Natalia Díaz-Rodríguez and Fernando Bobillo.

M. 16:50-18:20 **Session 11.C.4: SS.29. Uncertainty in medicine**
Chairperson: Anna Stachowiak

Modelling Medical Uncertainties with Use of Fuzzy Sets and Their Extensions.
Patryk Żywica.

An uncertainty aware medical diagnosis supportsystem.
Krzysztof Dyczkowski, Anna Stachowiak, Andrzej Wójtowicz and Patryk Żywica.

Diverse classes of interval-valued aggregation functions in medical diagnosis support.
Urszula Bentkowska and Barbara Pękala.

On Fuzzy Compliance for Clinical Protocols.
Anna Wilbik, Ivo Kuiper, Walther van Mook, Dennis Bergmans, Serge Heines and Irene Vanderfeesten.

M. 20:00 Welcome cocktail

TUESDAY 12th

Tu. 9:00-10:00 **Plenary talk: Uncertainty Management with Fuzzy Sets, Rough Sets, Interval Sets, Shadowed Sets, and Three-Way Decisions**
Speaker: Prof. Yiyu Yao
Chairperson: Prof. Jesús Medina

Tu. 10:00-11:00 **Session 12.A.1: SS.4. Current techniques to model, process and describe time series.**
Chairpersons: Juan Moreno-García and Luis Rodríguez-Benítez

Forecasting energy demand by clustering smart metering time series
Christian Bock.

Linguistic description of the evolution of stress level using fuzzy deformable prototypes.
Francisco P. Romero, José A. Olivas and Jesús Serrano-Guerrero.

Model averaging approach to forecasting the general level of mortality.
Marcin Bartkowiak, Katarzyna Kaczmarek-Majer, Aleksandra Rutkowska and Olgierd Hryniewicz.

Tu. 10:00-11:00 **Session 12.A.2: SS.25. Rough and Fuzzy Similarity Modelling Tools I**
Chairperson: Lukasz Sosnowski

Similarity-Based Accuracy Measures for Approximate Query Results.
Agnieszka Chądzyńska-Krasowska.

Object [Re]Cognition with Similarity.
Łukasz Sosnowski and Julian Skirzyński.

How to Match Jobs and Candidates - A Recruitment Support System Based on Feature Engineering and Advanced Analytics.
Andrzej Janusz, Sebastian Stawicki, Michał Drewniak, Krzysztof Ciebiera, Dominik Ślęzak and Krzysztof Stencel.

Tu. 10:00-11:00 **Session 12.A.3: SS.5. Decision Making modeling and applications I**
Chairperson: Rocío de Andrés Calle

On the structure of acyclic binary relations.
José C. R. Alcantud, María J. Campión, Juan C. Candeal, Raquel G. Catalán and Esteban Induráin.

Extracting Decision Rules from Qualitative Data via Sugeno Utility Functionals.
Quentin Brabant, Miguel Couceiro, Didier Dubois, Henri Prade and Agnès Rico.

An IoT Control System for wind power generators.
Marouane Salhaoui, Mounir Arioua, Antonio Guerrero-González and María Socorro García Cascales.

Tu.10:00-11:00 Session 12.A.4: SS.2 Aggregation Operators, Fuzzy Metrics and Applications III
Chairperson: Tomasa Calvo

On the migrativity property for uninorms and nullnorms.
Emel Aşıcı.

Comparison of Fuzzy Integral-Fuzzy Measure based Ensemble Algorithms with the State-of-the-art Ensemble Algorithms.
Utkarsh Agrawal, Tony Pinar, Christian Wagner, Timothy Havens, Daniele Soria and Jonathan Garibaldi.

Application of Aggregation Operators to Assess the Credibility of User-Generated Content in Social Media.
Gabriella Pasi and Marco Viviani.

Tu. 11:00-11:30 Coffee Break

Tu. 11:30-13:30 Session 12.B.1: SS.27. Soft Computing in Information Retrieval and Sentiment Analysis.
Chairperson: Jesús Serrano Guerrero

Obtaining WAPO-Structure through Inverted Indexes.
Úrsula Torres-Parejo, Jesús Roque Campaña, María Amparo Vila and Miguel Delgado.

Automatic Expansion of Spatial Ontologies for Geographic Information Retrieval.
Manuel E. Puebla-Martínez, José M. Perea-Ortega, Alfredo Simón-Cuevas and Francisco P. Romero.

Increasing Performance via Gamification in a Volunteer-Based Evolutionary Computation System.
Mario García-Valdéz, Juan J. Merelo, Lucero Lara and Pablo García-Sánchez.

Using syntactic analysis to enhance aspect based sentiment analysis.
Juan Moreno-García and Jesús Rosado.

A probabilistic author-centered model for Twitter discussions.
Teresa Alsinet, Josep Argelich, Ramón Béjar, Francesc Esteva and Lluís Godo.

A concept-based text analysis approach using knowledge graphs.
Wenny Hojas-Mazo, Alfredo Simón-Cuevas, Manuel De la Iglesia Campos, Francisco P. Romero and José A. Olivas.

Tu. 11:30-13:30 **Session 12.B.2: SS.25. Rough and Fuzzy Similarity Modelling Tools II**
Chairperson: Marcin Szczuka

Defuzzyfication in Interpretation of Comparator Networks.
Łukasz Sosnowski and Marcin Szczuka.

A Comparison of Characteristic Sets and Generalized Maximal Consistent Blocks in Mining Incomplete Data.
Patrick G. Clark, Cheng Gao, Jerzy W. Grzymala-Busse and Teresa Mroczek

Rules Induced from Rough Sets in Information Tables with Continuous Values.
Michinori Nakata, Hiroshi Sakai and Keitarou Hara.

A Linear Model for Three-Way Analysis of Facial Similarity.
Daryl Hepting, Hadeel Bin Amer and Yiyu Yao.

Empirical Comparison of Distances for Agglomerative Hiearchical Clustering.
Shusaku Tsumoto.

Attribute Reduction of Set-valued Decision Information System.
Jun Hu, Siyu Huang and Rui Shao.

Tu. 11:30-13:30 **Session 12.B.3: SS.5. Decision Making modeling and applications. II**
Chairperson: María Dolores García-Sanz

Ideal and Real Party Positions in the 2015-2016 Spanish General Elections.
M.D. García-Sanz, I. Llamazares and M.A. Manrique.

DNBMA: A double normalization-based multi-aggregation method.
Huchang Liao, Xingli Wu and Francisco Herrera.

Design of a Decision Support System for Buried Pipeline Corrosion Assessment.
Laurence Boudet, Jean-Philippe Poli, Alicia Bel, François Castillon, Frédéric Gaigne and Olivier Casula.

How Potential BLFs Can Help to Decide under Incomplete Knowledge.
Florence Dupin De Saint-Cyr and Guillaume Romain.

Sequential decision making under uncertainty: ordinal uninorms vs. the Hurwicz criterion.
Hélène Fargier and Romain Guillaume.

A proposal to measure human group behaviour stability.
Teresa González-Arteaga, José Manuel Cascón and Rocío De Andrés.

Tu. 11:30-13:30 Session 12.B.4: SS.21. New trends in data aggregation
Chairpersons: Bernard De Baets and Raúl Pérez Fernández

The median procedure as an example of penalty-based aggregation of binary relations.
Raúl Pérez-Fernández and Bernard De Baets.

Least median of squares (LMS) and least trimmed squares (LTS) fitting for the weighted arithmetic mean.
Gleb Beliakov, Marek Gagolewski and Simon James.

Combining absolute and relative information in studies on food quality.
Marc Sader, Raúl Pérez-Fernández and Bernard De Baets.

Robust On-Line Streaming Clustering.
Omar Ibrahim, Yizhuo Du and James Keller.

Twofold binary image consensus for medical imaging meta-analysis.
Carlos López-Molina, Javier Sánchez Ruiz de Gordoa, M. Victoria Zelaya Huerta and Bernard De Baets.

Tu. 11:30-13:30 Session 12.B.4: SS.21. Fuzzy Logic and Artificial Intelligence Problems (I)
Parallel Workshop. Chairpersons: Daniel Sánchez
http://decsai.ugr.es/pi/lidvis/IPMU2018Session.html

Tu. 13:30-15:00 Lunch

Tu. 15:00-16:00 Plenary talk: Consensus in Group Decision Making and Social Networks
Speaker: Prof. Enrique Herrera-Viedma
Chairperson: José Luis Verdegay

Tu. 16:00-16:20 Coffee break

Tu. 16:20-18:00 Session 12.C.1: SS.23. Pre-aggregation functions and generalized forms of monotonicity
Chairperson: Humberto Bustince

Penalty-based functions defined by pre-aggregation functions
Graçaliz Dimuro, Radko Mesiar, Humberto Bustince, Benjamín Bedregal, José Antonio Sanz Delgado and Giancarlo Lucca

Strengthened ordered directional and other generalizations of monotonicity for aggregation functions.
Mikel Sesma-Sara, Laura De Miguel, Julio Lafuente, Edurne Barrenechea, Radko Mesiar and Humberto Bustince.

A study of different families of fusion functions for combining classifiers in the One-vs-One strategy.
Mikel Uriz, Daniel Paternain, Aranzazu Jurio, Humberto Bustince and Mikel Galar.

Aggregation functions based on deviations.
Marián Decký, Radko Mesiar and Andrea Stupňanová.

Image feature extraction using OD-monotone functions.
Cedric Marco-Detchart, Carlos López-Molina, Javier Fernández, Miguel Pagola and Humberto Bustince.

Tu. 16:20-18:00 **Session 12.C.2: SS.9. Fuzzy Logic and Artificial Intelligence Problems (II)**
Chairperson: Juan Luis Castro

Interval Type-2 Intuitionistic Fuzzy Logic Systems - A Comparative Evaluation.
Imo Eyoh, Robert John and Geert De Maere.

Merging information using Uncertain Gates: An application to Educational Indicators.
Guillaume Petiot.

New negations on the type-2 membership degrees.
Carmen Torres-Blanc, Susana Cubillo and Pablo Hernández-Varela.

Combining Weighted Description Logic with Fuzzy Logic for Decision Making.
Nadine Mueller, Klemens Schnattinger and Heike Walterscheid.

On Hash Bipolar Division: An Enhanced Processing of Novel and Conventional Forms of Bipolar Division.
Noussaiba Benadjimi, Walid-Khaled Hidouci and Allel Hadjali.

Tu. 16:20-18:00 **Session 12.C.3: SS.5. Decision Making modeling and applications III**
Chairperson: Teresa González-Arteaga

Applying Suitability Distributions in a Geological Context.
Robin De Mol and Guy De Tré.

Identifying Criteria Most Influencing Strategy Performance: Application to Humanitarian Logistical Strategy Planning.
Cécile L'Heritier, Abdelhak Imoussaten, Sébastien Harispe, Gilles Dusserre, Benoît Roig.

The use of fuzzy linguistic information and Fuzzy Delphi method to validate by consensus a questionnaire in a Blended-Learning environment.
Jeovani Morales, Rosana Montes, Noe Zermeño, Jerónimo Durán and Francisco Herrera

On the Interaction between Feature Selection and Parameter Determination in Fuzzy Modelling.
Peipei Chen, Caro Fuchs, Anna Wilbik, Tak-Ming Chan, Saskia van Loon, Arjen-Kars Boer, Xudong Lu, Volkher Scharnhors and Uzay Kaymak.

FS4RVDD: A Feature Selection Algorithm for Random Variables with Discrete Distribution.
Fiorella Cravero, Santiago Schustik, María Jimena Martínez, Mónica Fátima Díaz and Ignacio Ponzoni.

Tu. 18:00-20:00 EUSFLAT Meeting

WEDNESDAY 13th

W. 9:00-10:00 **Plenary talk: Uncertainty quantification of many-valued events: betting methods, geometry and reasoning**
Speaker: Prof. Lluis Godo
Chairperson: Prof. Manuel Ojeda-Aciego

W. 10:00-11:00 **Session 13.A.1: General Track**
Chairperson: Jesús Medina

Clustering of Propositions Equipped with Uncertainty.
Marek Reformat, Jesse Xi Chen and Ronald R. Yager.

Co-words Analysis of the Last Ten Years of the International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems.
Manuel Jesús Cobo Martin, Wanru Wang, Sigifredo Laengle, José M. Merigó, Dejian Yu and Enrique Herrera-Viedma.

Robust Lookup Table Controller Based on Piecewise Multi-Linear Model for Nonlinear Systems with Parametric Uncertainty.
Tadanari Taniguchi and Michio Sugeno.

W. 10:00-11:00 **Session 13.A.2: General Track**
Chairperson: Eloísa Ramírez-Poussa

A New Approach to Hellwig's Method of Data Reduction for Atanassov's Intuitionistic Fuzzy Sets.
Eulalia Szmidt and Janusz Kacprzyk.

Towards a Semantic Gas Source Localization under Uncertainty.
Javier Monroy, José-Raúl Ruiz-Sarmiento, Francisco-Ángel Moreno, Cipriano Galindo and Javier González-Jiménez.

A Novel Uncertainty Quantification Method for Efficient Global Optimization.
Bas van Stein, Hao Wang, Wojtek Kowalczyk and Thomas Bäck.

W. 10:00-11:00 **Session 13.A.3: General Track**
Chairperson: María Eugenia Cornejo

Topological MI-groups: Initial Study.
Michal Holčapek and Nicole Škorupová.

On Cantor's Theorem for Fuzzy Power Sets.
Michal Holčapek.

The Relationship Between Graphical Representations of Regular Vine Copulas and Polytrees.
Diana Carrera, Roberto Santana and José A. Lozano.

W. 10:00-11:00 **Session 13.A.4: SS.22. Optimization models for modern analytics I**
Chairperson: José Luis Verdegay

Implementing data envelopment analysis in an uncertain perception-based online evaluation environment.
Debora Di Caprio and Francisco Javier Santos Arteaga.

Constraint Shortest Path Problem in a Network with Intuitionistic Fuzzy Arc Weights.
Homayun Motameni and Ali Ebrahimnejad.

A comparison between NARX Neural Networks and Symbolic Regression: An application for energy consumption forecasting.
Ramón Rueda Delgado, Luis G. Baca Ruíz, Manuel Pegalajar Cuéllar, Miguel Delgado Calvo-Flores and María Del Carmen Pegalajar Jiménez.

W. 11:00-11:30 Coffee Break

W. 11:30-13:40 **Session 13.B.1: SS.1. Advances on Explainable Artificial Intelligence**
Chairpersons: José M. Alonso and Luis Magdalena.

A Bibliometric Analysis of the Explainable Artificial Intelligence Research Field.
Jose M. Alonso, Ciro Castiello and Corrado Mencar.

Do Hierarchical Fuzzy Systems really improve interpretability?
Luis Magdalena.

Human Players versus Computer Games Bots: A Turing test based on Linguistic Description of Complex Phenomena and Restricted Equivalence Functions.
Clemente Rubio-Manzano, Tomás Lermanda-Senoceain, Christian Vidal-Castro, Alejandra Segura-Navarrete and Claudia Martínez-Araneda.

Reinterpreting interpretability for fuzzy linguistic descriptions of data.
Alejandro Ramos and Martín Pereira-Fariña.

Tell Me Why: Computational Explanation of Conceptual Similarity Judgments.
Davide Colla, Enrico Mensa, Daniele P. Radicioni and Antonio Lieto.

Multi-operator Decision Trees for Explainable Time-Series Classification.
Vera Shalaeva, Sami Alkhoury, Julien Marinescu, Cécile Amblard and Gilles Bisson.

Comparison-based Inverse Classification for Interpretability in Machine Learning.
Thibault Laugel, Marie-Jeanne Lesot, Christophe Marsala, Xavier Renard and Marcin Detyniecki.

W. 11:30-13:40 **Session 13.B.2: SS.17.Mathematical Fuzzy Logic**
Chairperson: Lluis Godo

Mapping Utilities to Transitive Preferences.
Thomas A. Runkler.

On the structure of group-like FLe-chains.
Sándor Jenei.

First steps towards harnessing partial functions in fuzzy type theory.
Vilém Novák.

Logics for strict coherence and Carnap-regular probability functions.
Tommaso Flaminio.

Connecting systems of mathematical fuzzy logic with fuzzy concept lattices.
Pietro Codara, Francesc Esteva, Lluís Godo and Diego Valota.

Characterizing fuzzy y-models in multi-adjoint normal logic programming.
M. Eugenia Cornejo, David Lobo and Jesús Medina.

W. 11:30-13:40 **Session 13.B.3: SS.13. Imprecise Probabilities: foundations and applications**
Chairperson: Enrique Miranda

Natural extension of choice functions.
Arthur Van Camp, Enrique Miranda and Gert de Cooman.

Approximations of coherent lower probabilities by 2-monotone capacities.
Ignacio Montes, Enrique Miranda and Paolo Vicig.

Web Apps & Imprecise Probabilitites.
Jorge Castro, Joaquim Gabarro and Maria Serna.

Conditional submodular coherent risk measures.
Giulianella Coletti, Davide Petturiti and Barbara Vantaggi.

Virtual Subconcept Drift Detection in Discrete Data Using Probabilistic Graphical Models.
Rafael Cabañas de Paz, Andrés Cano, Manuel Gómez-Olmedo, Andrés R. Masegosa and Serafín Moral.

W. 11:30-13:40 **Session 13.B.4: SS.22. Optimization models for modern analytics II**
Chairperson: Ali Ebrahimnejad

MOLP Approach for Solving Transportation Problems with Intuitionistic Fuzzy Costs.
Ali Ebrahimnejad and José Luis Verdegay.

Context-based Decision and Optimization: the Case of the Maximal Coverage Location Problem.
María Teresa Lamata, David Pelta, Alejandro Rosete and José Luis Verdegay.

Reliability improvement of Odour Detection Thresholds bibliographic data.
Pascale Montreer, Stefan Janaqi, Stéphane Cariou, Mathilde Chaignaud, Isabelle Betremieux, Philippe Ricoux, Frédéric Picard, Sabine Sirol, Budagwa Assumani and Jean-Louis Fanlo.

A Decision Support System based on a Hybrid Genetic Local Search heuristic for solving the Dynamic Vehicle Routing Problem: Tunisian Case.
Ines Sbai, Olfa Limem, Saoussen Krichen.

W. 13:40-15:00 Lunch

W. 15:00-16:30 ---

W. 16:30-19:00 Social event

W. 20:00 Gala dinner

THURSDAY 14th

T. 10:00-11:00 **Plenary talk: Multisource Geo Big Data for Earth Observation: Challenges Offered by Fuzzy Approaches**
Speaker: Prof. Gloria Bordogna
Chairperson: Bernadette Bouchon-Meunier

T. 11:00-11:30 Coffee Break

T. 11:30-13:30 **Session 14.B.1: SS.8. Fuzzy Implication Functions**
Chairpersons: Sebastia Massanet and Michal Baczynski

Fuzzy Boundary Weak Implications.
Hua-Wen Liu and Michał Baczyński.

On linear and quadratic constructions of fuzzy implication functions.
Sebastia Massanet, Juan Vicente Riera and Joan Torrens.

On the characterization of a family of generalized Yager's implications.
Raquel Fernandez-Peralta and Sebastia Massanet.

Generalized Modus Ponens for (U,N)-implications.
Margarita Mas, Daniel Ruiz-Aguilera and Joan Torrens.

Dependencies between some types of fuzzy equivalences.
Urszula Bentkowska and Anna Król.

Selected Properties of Generalized Hypothetical Syllogism Including the Case of R-implications
Michał Baczyński and Katarzyna Miś.

T. 11:30-13:30 **Session 14.B.2: SS.10. Fuzzy Mathematical Analysis and Applications.**
Chairperson: Manuel Ojeda-Aciego

Artificial neural networks and fuzzy logic for specifying the color of an image using munsell soil-color charts.
María *Del Carmen Pegalajar, Manuel Sánchez-Marañón, Luis Gonzaga Baca-Ruiz, Luis Mansilla and Miguel Delgado Calvo-Flores.*

Steinhaus transforms of fuzzy string distances in computational linguistics.
Anca Dinu, Liviu P. Dinu, Laura Franzoi and Andrea Sgarro.

Size-based super level measures on discrete space.
Jana Borzová, Lenka Halčinová and Jaroslav Šupina.

Modified Methods of Capital Budgeting under Uncertainties: An Approach Based on Fuzzy Numbers and Interval Arithmetic.
Antonio Carlos de Souza Sampaio Filho, Marley M. B. R. Vellasco and Ricardo Tanscheit.

Solving job-shop scheduling problems with fuzzy processing times and fuzzy due dates.
Camilo Alejandro Bustos-Tellez, Jhoan Sebastian Tenjo-Garcia and Juan Carlos Figueroa-García.

T. 11:30-13:30 Session 14.B.3: SS.3. Belief Function Theory and its Applications
Chairperson: Didier Coquin

Measuring features strength in probabilistic classification.
Rosario Delgado and Xavier-Andoni Tibau.

DETD: Dynamic policy for case base maintenance based on EK-NNclus algorithm and case Types Detection.
Safa Ben Ayed, Zied Elouedi and Eric Lefèvre

Ensemble Enhanced Evidential k-NN classifier through rough set reducts.
Asma Trabelsi, Zied Elouedi and Eric Lefèvre.

Towards a Hybrid User and Item-based Collaborative Filtering under the Belief Function Theory.
Raoua Abdelkhalek, Imen Boukhris and Zied Elouedi.

Evidential Top-k Queries Implementation: Algorithms and Experiments.
Fatma Ezzahra Bousnina, Mouna Chebbah, Mohamed Anis Bach Tobji, Allel Hadjali and Boutheina Ben Yaghlane.

Independence of Sources in Social Networks.
Manel Chehibi, Mouna Chebbah and Arnaud Martin.

T. 11:30-13:30 Session 14.B.4: SS.30. Uncertainty in Video/Image Processing (UVIP)
Chairperson: Enrique Domínguez

Foreground detection enhancement using Pearson correlation filtering.
Rafael M. Luque-Baena, Miguel A. Molina-Cabello, Ezequiel López-Rubio and Enrique Domínguez.

Identifying pixels classified uncertainties ckMeansImage algorithm.
Rogério R. De Vargas, Ricardo Freddo, Cristiano Galafassi, Sidnei Gass, Alexandre Russini and Benjamín Bedregal.

Automatic Detection of Thistle-Weeds in Cereal Crops from Aerial RGB Images
Camilo Franco, Carely Guada, J. Tinguaro Rodríguez, Jon Nielsen, Jesper Rasmussen, Daniel Gómez and Javier Montero.

Navigating the meaning and uncertainty hierarchy within image scenes and the words that describe them.
Lauren Barghout.

T. 13:30-15:00 Lunch

T. 15:00-16:00 **Round table: ICTs and CEI·MAR**

T. 16:00-16:30 Coffee Break

T. 16:30-18:00 **Session 14.C.1: SS.6. Discrete models and Computational Intelligence. Chairperson: László Kóczy**

T-overlap Functions: a generalization of bivariate overlap functions by t-norms.
Hugo Zapata, Graçaliz Dimuro, Javier Fernández and Humberto Bustince.

On the Existence and Uniqueness of Fixed Points of Fuzzy Cognitive Maps.
István Harmati, Miklós Hatwágner and László T. Kóczy.

Searching Method of Fuzzy Internally Stable Set as Fuzzy Temporal Graph Invariant.
Alexander Bozhenyuk, Stanislav Belyakov, Margarita Knyazeva and Igor Rozenberg.

Prioritisation of Nielsen's Usability Heuristics for User Interface Design Using Fuzzy Cognitive Maps.
Rita Amro, Saransh Dhama, Muhanna Muhanna and László T. Kóczy.

Discrete Bacterial Memetic Evolutionary Algorithm for the Time Dependent Traveling Salesman Problem.
Boldizsár Tüű-Szabó, Péter Földesi and László T. Kóczy.

T. 16:30-18:00 **Session 14.C.2: SS.14. Logical methods in mining knowledge from big data Chairperson: Vilém Novák**

Fuzzy association rules on data with undefined values.
Petra Murinová, Viktor Pavliska and Michal Burda.

Subproduct and grouping features in fuzzy relational compositions.
Nhung Cao, Martin Štěpnička, Michal Burda and Aleš Dolný.

Compositions of partial fuzzy relations.
Nhung Cao and Martin Štěpnička.

Towards a hierarchical extension of contextual bipolar queries.
Janusz Kacprzyk and Sławomir Zadrożny.

Quantification over Undefined Truth Values.
Martina Daňková.

T. 16:30-18:00 **Session 14.C.3: General track**
Chairperson: David Pelta

Predicting First-Episode Psychosis Associated with Cannabis Use with Artificial Neural Networks and Deep Learning.
Daniel Stamate, Wajdi Alghamdi, Daniel Stahl, Ida Pu, Fionn Murtagh, Danielle Belgrave, Robin Murray and Marta di Forti.

Opinion mining in social networks for Algerian dialect.
Mehdi Bettiche, Moncef Zakaria Mouffok and Chahnez Zakaria.

Representing Hypoexponential Distributions in Continuous Time Bayesian Networks.
Manxia Liu, Fabio Stella, Arjen Hommersom and Peter Lucas.

FRIDAY 15th

F. 9:00-10:00 **Plenary talk: Biological Apps: Rapidly Converging Technologies for Living Information Processing**
Speaker: Prof. Natalio Krasnogor
Chairperson: Prof. Irina Perfilieva

F. 10:00-11:00 **Session 15.A.1: SS.12. Fuzzy transforms: theory and applications to data analysis and processing I**
Chairperson: Irina Perfilieva

Axiomatic of Inverse Lattice-valued F-transform.
Jiří Močkoř.

Why Triangular Membership Functions Are Often Efficient in F-Transform Applications: Relation to Probabilistic and Interval Uncertainty and Haar Wavelets.
Olga Kosheleva and Vladik Kreinovich.

Enhanced F-transform exemplar based image inpainting.
Pavel Vlašánek.

F. 10:00-11:00 **Session 15.A.2: SS.26. Soft Computing for Decision Making in Uncertainty I**
Chairperson: Yuriy P. Kondratenko

Missing data imputation by LOLIMOT and FSVM/FSVR algorithms with a novel approach: A Comparative Study.
Fatemeh Fazlikhani, Pegah Motakefi and Mir Mohsen Pedram.

Two Modifications of the Automatic Rule Base Synthesis for Fuzzy Control and Decision Making Systems.
Yuriy Kondratenko, Oleksiy Kozlov and Oleksiy Korobko.

Decision making under incompleteness based on soft set theory.
José Carlos R. Alcantud and Gustavo Santos-García.

F. 10:00-11:00 **Session 15.A.3: General track**
Chairperson: David A. Pelta

A Proposal for Adaptive Maps.
Marina Torres, David A. Pelta and José Luis Verdegay.

Using inductive rule learning techniques to learn planning domains.
José Á. Segura-Muros, Raúl Pérez and Juan Fernández-Olivares.

Divergence Measures and Approximate Algorithms for Valuation Based Systems.
Serafín Moral.

F. 10:00-11:00 **Session 15.A.4: SS.20. Metaheuristics and Machine Learning I**
Chairperson: Patricia Ruiz

Evidential Bagging: Combining Heterogeneous Classifiers in the Belief Functions Framework.
Nicolas Sutton-Charani, Abdelhak Imoussaten, Sébastien Harispe and Jacky Montmain.

Dealing with Epistemic Uncertainty in Multi-objective Optimization: A Survey.
Oumayma Bahri and El-Ghazali Talbi.

Analyzing the Influence of LLVM Code Optimization Passes on Software Performance.
Juan Carlos de la Torre, Patricia Ruiz, Bernabé Dorronsoro and Pedro L. Galindo.

F. 11:00-11:30 Coffee Break

F. 11:30-13:30 **Session 15.B.1: SS.12. Fuzzy transforms: theory and applications to data analysis and image processing II**
Chairperson: Jiří Močkoř

A Novel Approach to The Discrete Fuzzy Transform of Higher Degree.
Linh Nguyen and Michal Holčapek.

Lattice-Valued F-Transforms as Interior Operators of L-fuzzy Pretopological Spaces.
Irina Perfilieva, S. P. Tiwari and Anand P. Singh.

Modified F-transform Based on B-splines.
Martins Kokainis and Svetlana Asmuss.

Collocation method for linear BVPs via B-spline based fuzzy transform.
Martins Kokainis and Svetlana Asmuss.

F. 11:30-13:30 **Session 15.B.2: SS.26. Soft Computing for Decision Making in Uncertainty II**
Chairperson: Yuriy P. Kondratenko

Fuzzy relational compositions can be useful for customers credit scoring in financial industry.
Soheyla Mirshahi and Nhung Cao.

Intelligent Decision Support System for Selection of the Rational Model of University-Industry Cooperation.
Yuriy Kondratenko, Galyna Kondratenko and Ievgen Sidenko.

Strategy to Managing Mixed Datasets with Missing Items.
Inna Skarga-Bandurova, Tetiana Biloborodova and Yuriy Dyachenko.

Predicting Opponent's Moves for Improving Hearthstone AI.
Alexander Dockhorn, Max Frick, Ünal Akkaya and Rudolf Kruse.

A New Generic Framework for Argumentation-based Negotiation using Case-Based Reasoning.
Rihab Bouslama, Raouia Ayachi and Nahla Ben Amor.

Personality determination of an individual through neural networks.
Rubén Sánchez, Manuel Capel, Celina Jiménez, Gonzalo Rodríguez-Fraile and María del Carmen Pegalajar.

F. 11:30-13:30 **Session 15.B.3: SS.19. Measures of comparison and entropies for fuzzy sets and their extensions**
Chairperson: Susana Montes

On Dissimilarity Measures at the Fuzzy Partition Level.
Grégory *Smits, Olivier Pivert and Toan Ngoc Duong.*

Fuzzy Extensions of Conceptual Structures of Comparison.
Didier Dubois, Henri Prade and Agnès Rico.

Monotonicity of a profile of rankings with ties.
Raúl Pérez-Fernández, Irene Díaz, Susana Montes and Bernard De Baets.

Consistency properties for fuzzy choice functions: an analysis with the Lukasiewicz t-norm.
Susana Díaz, José Carlos R. Alcantud and Susana Montes.

Entropy and Monotonicity.
Bernadette Bouchon-Meunier and Christophe Marsala.

Comparison between ordered ordinary fuzzy multiset.
Ángel Riesgo, Pedro Alonso, Irene Díaz, Vladimír Janiš, Vladimír Kobza and Susana Montes.

F. 11:30-13:30 Session 15.B.4: SS.20. Metaheuristics and Machine Learning II
Chairperson: Bernabé Dorronsoro

Finding the most Influential Parameters of Coalitions in PSO-CO Algorithm.
Patricia Ruiz, Bernabé Dorronsoro, Juan Carlos de la Torre and Juan Carlos Burguillo.

A comparative analysis of accurate and robust bi-objective scheduling heuristics for datacenters.
Sergio Nesmachnow and Bernabé Dorronsoro.

Applying Genetic Algorithms for the Improvement of an Autonomous Fuzzy Driver for Simulated Car Racing.
Mohammed Salem, Antonio Miguel Mora, Juan J. Merelo and Pablo García-Sánchez.

A self-organizing ensemble of deep neural networks for the classification of data from complex processes.
Niclas Ståhl, Göran Falkman, Gunnar Mathiason and Alexander Karlsson.

Fuzzy rule learning for material classification from imprecise data.
Arnaud Grivet Sébert and Jean-Philippe Poli.

Credal C4.5 with refinement of parameters.
Carlos Mantas, Joaquín Abellán, Javier Castellano, José Cano and Serafín Moral-García.

13:30 CLOSING SESSION

Efficient Binary Fuzzy Measure Representation and Choquet Integral Learning

Muhammad Aminul Islam, Derek Anderson, Xiaoxiao Du, Timothy Havens and Christian Wagner

The Choquet integral (ChI), a parametric function for information aggregation, is parameterized by the fuzzy measure (FM), which has 2^N real-valued variables for N inputs. However, the ChI incurs huge storage and computational burden due to its exponential complexity relative to N and, as a result, its calculation, storage, and learning becomes intractable for even modest sizes (e.g., $N = 15$). Inspired by empirical observations in multi-sensor fusion and the more general need to mitigate the storage, computational, and learning limitations, we previously explored the binary ChI (BChI) relative to the binary fuzzy measure (BFM). The BChI is a natural fit for many applications and can be used to approximate others. Previously, we investigated different properties of the BChI and we provided an initial representation. In this article, we propose a new efficient learning algorithm for the BChI, called EBChI, by utilizing the BFM properties that add at most one variable per training instance. Furthermore, we provide an efficient representation of the BFM (EBFM) scheme that further reduces the number of variables required for storage and computation, thus enabling the use of the BChI for "big N". Finally, we conduct experiments on synthetic data that demonstrate the efficiency of our proposed techniques.

Mortality Rates Smoothing Using Mixture Function

Samuel Hudec, Jana Špirková

The paper offers a description of the new method of a smoothing of the mortality rates using the so-called moving mixture functions. Mixture functions represent a special class of weighted averaging functions where weights are determined by continuous, input values dependent, weighting functions. If they are increasing, they form an important class of aggregation functions. Such mixture functions are more flexible than the standard weighted arithmetic mean, and their weighting functions allow one to penalize or reinforce inputs based on their magnitude. The advantages of this method are that the weights of the input values depend on ourselves and coefficients of weighting functions can be changed each year so that the mean square error is minimized. Moreover, the paper offers the impact of this method on the amount of whole life pension annuities.

Nullnorms and t-operators on bounded lattices: coincidence and differences

Slavka Bodjanova and Martin Kalina

T-operators were defined on $[0, 1]$ by M. Mas et al. in 1999. In 2001, T. Calvo et al. introduced the notion of nullnorms, also on $[0, 1]$. Both of these operations were defined as generalizations of t-norms and t-conorms. As Mas et al. in 2002 pointed out, t-operators and nullnorms coincide on $[0, 1]$. Afterwards, only nullnorms were studied and later generalized as operations on bounded lattices. Our intention is to introduce also t-operators as operations on bounded lattices. We will show that, on bounded lattices, nullnorms and t-operators need not coincide. We will explore conditions under which one of these operations is necessarily the other one, and conditions under which they differ.

On the use of fuzzy preorders in multi-robot task allocation problem

José Guerrero, Juan-José Miñana and Óscar Valero.

This paper addresses the multi-robot task allocation problem. In particular, given a collection of tasks and robots, we focus on how to select the best robot to execute each task by means of the so-called response threshold method. In the aforesaid method, each robot decides to leave a task and to perform another one (decides to transit) following a probability (response functions) that depends mainly of a stimulus and the current task. The probabilistic approaches used to model the transitions present several handicaps. To solve these problems, in a previous work, we introduced the use of indistinguishability operators to model response functions and possibility theory instead of probability. In this paper we extend the previous work in order to be able to model response functions when the stimulus under consideration depends on the distance between tasks and the utility of them. Thus, the resulting response functions that model transitions in the Markov chains must be asymmetric. In the light of this asymmetry, it seems natural to use fuzzy preorders in order to model the system's behaviour. The results of the simulations executed in Matlab validate our approach and they show again how the possibilistic Markov chains outperform their probabilistic counterpart.

On the problem of aggregation of partial T-indistinguishability operators

Tomasa Calvo Sánchez, Pilar Fuster-Parra and Óscar Valero.

In this paper we focus our attention on exploring the aggregation of partial T–indistinguishability operators (relations). Concretely we characterize, by means

of (T-$T_{\min}$)-tuples, those functions that allow to merge a collection of partial T–indistinguishability operators into a single one. Moreover, we show that monotony is a necessary condition to ensure that a function aggregates partial T–indistinguishability operators into a new one. We also provide that an inter–exchange composition function condition is a sufficient condition to guarantee that a function aggregates partial T–indistinguishability operators. Finally, examples of this type of functions are also given.

Study of the relevance of objects and attributes of L-fuzzy contexts using overlap indexes

Cristina Alcalde and Ana Burusco

Objects and attributes play an important role in an L-fuzzy context. From the point of view of the L-fuzzy concepts, some of them can be more relevant than others. Besides, the number of objects and attributes of the L-fuzzy context is one of the most important factors that influence in the size of the L-fuzzy concept lattice. In this paper, we define different rankings for the objects and the attributes according to their relevance in the L-fuzzy concept lattice and using different overlap indexes. These rankings can be useful for the reduction of the L-fuzzy context size.

FCA attribute reduction in information systems

María José Benítez-Caballero, Jesús Medina and Eloísa Ramírez-Poussa

One of the main targets in formal concept analysis (FCA) and in rough set theory (RST) is the reduction of redundant information. Feature selection mechanisms have been studied separately in many works. In this paper, we analyse the result of applying the reduction mechanisms given in FCA to RST, and give interpretations of such reductions.

Formal Concept Analysis and structures underlying Quantum Logics

Ondrej Krídlo and Manuel Ojeda-Aciego

A Hilbert space H induces a formal context, the Hilbert formal context $\overline{H}$, whose associated concept lattice is isomorphic to the lattice of closed subspaces of H. This set of closed subspaces, denoted $\mathcal{C}(H)$, is important in the development of quantum logic and, as an algebraic structure, corresponds to a so-called "propositional system," that is, a complete, atomistic, orthomodular lattice which satisfies the covering law. In this paper, we continue with our study of the Chu construction by introducing the Chu correspondences between

Hilbert contexts, and showing that the category of Propositional Systems, PropSys, is equivalent to the category of $\mathrm{ChuCors}_{\mathcal{H}}$ of Chu correspondences between Hilbert contexts.

Directness in Fuzzy Formal Concept Analysis

Pablo Cordero, Manuel Enciso and Ángel Mora

Implicational sets have showed to be an efficient tool for knowledge representation. An active area is the definition of some canonical sets (basis) to efficiently specify and manage the information specified with implications. Unlike in classical formal concept analysis, in the fuzzy framework it is an open issue to design methods to efficiently compute the corresponding basis from a given set of fuzzy implications and, later, manage it in an automatic way. In this work we use Simplification Logic to tackle this issue. More specifically, we cover the following stages related to this problem: the generalization of the Simplification logic to an arbitrary complete residuated lattice changing its semantic, the introduction of the syntactic closure and an algorithm to compute it, the definition of a fuzzy direct basis with minimum size, providing the so-called directness property as well, and, finally the design of an algorithm to compute this basis.

Formal Independence Analysis

Francisco J. Valverde-Albacete, Carmen Peláez-Moreno, Inma P. Cabrera, Pablo Cordero and Manuel Ojeda-Aciego

In this paper we propose a new lens through which to observe the information contained in a formal context. Instead of focusing on the hierarchical relation between objects or attributes induced by their incidence, we focus on the "unrelatedness" of the objects with respect to those attributes with which they are not incident. The crucial order concept for this is that of maximal anti-chain and the corresponding representation capabilities are provided by Behrendt's theorem. With these tools we introduce the fundamental theorem of Formal Independence Analysis and use it to provide an example of what its affordances are for the analysis of data tables. We also discuss its relation to Formal Concept Analysis.

Spatio-temporal Drought Identification through Mathematical Morphology

Hilde Vernieuwe, Bernard De Baets and Niko E.C. Verhoest

Droughts are initiated by a lack of precipitation over a large area and a long period of time. In order to be able to estimate the possible impacts of droughts, it is important to identify and characterise these events. Describing a drought is,

however, not such an easy task as it represents a spatio-temporal phenomenon, with no clear start and ending, trailing from one place to another. This study tries to objectively identify droughts in space and time by applying operators from mathematical morphology. On the basis of the identified droughts, OWA operators are employed to characterise the events in order to aid farmers, water managers, *etc* in coping with these events.

Fuzzy Analysis of Sentiment Terms for Topic Detection Process in Social Networks

Karel Gutiérrez-Batista, Jesús R. Campaña, María-Amparo Vila and María J. Martin-Bautista

The aim of this paper is to analyze the influence of sentiment-related terms on the automatic detection of topics in social networks. The study is based on the use of an ontology, to which the capacity to gradually identify and discard sentiment terms in social network texts is incorporated, as these terms do not provide useful information for detecting topics. To detect these terms, we have used two resources focused on the analysis of sentiments. The proposed system has been assessed with real data sets of the social networks Twitter and Dreamcatcher in English and Spanish respectively.

Fuzzy association rules mining using Spark

Carlos Fernández-Bassso, M. Dolores Ruiz and María J. Martin-Bautista

Discovering new trends and co-occurrences in massive data is a key step when analysing social media, data coming from sensors, etc. Traditional Data Mining techniques are not able, in many occasions, to handle such amount of data. For this reason, some approaches have arisen in the last decade to develop parallel and distributed versions of previously known techniques. Frequent itemset mining is not an exception and in the literature there exist several proposals using not only parallel approximations but also Spark and Hadoop developments following the MapReduce philosophy of Big Data.

When processing fuzzy data sets or extracting fuzzy associations from crisp data the implementation of such Big Data solutions becomes crucial, since available algorithms increase their execution time and memory consumption due to the problem of not having Boolean items. In this paper, we first review existing parallel and distributed algorithms for frequent itemset and association rule mining in the crisp and fuzzy case, and afterwards we develop a preliminary proposal for mining not only frequent fuzzy itemsets but also fuzzy association rules. We also study the performance of the proposed algorithm in several datasets that have been conveniently fuzzyfied obtaining promising results.

A Typology of Data Anomalies

Ralph Foorthuis

Anomalies are cases that are in some way unusual and do not appear to fit the general patterns present in the dataset. Several conceptualizations exist to distinguish between different types of anomalies. However, these are either too specific to be generally applicable or so abstract that they neither provide concrete insight into the nature of anomaly types nor facilitate the functional evaluation of anomaly detection algorithms. With the recent criticism on 'black box' algorithms and analytics it has become clear that this is an undesirable situation. This paper therefore introduces a general typology of anomalies that offers a clear and tangible definition of the different types of anomalies in datasets. The typology also facilitates the evaluation of the functional capabilities of anomaly detection algorithms and as a framework assists in analyzing the conceptual levels of data, patterns and anomalies. Finally, it serves as an analytical tool for studying anomaly types from other typologies.

Two-sample dispersion tests for interval-valued data

Przemysław Grzegorzewski

The two-sample dispersion testing problem is considered. Two generalizations of the Sukhatme test for interval-valued data are proposed. These two versions correspond to different possible views on the interval outcomes of the experiment: the epistemic or the ontic one. Each view yields its own approach to data analysis which results in a different test construction and the way of carrying on the statistical inference.

IF-CLARANS: Intuitionistic Fuzzy Algorithm for Big Data Clustering

Hechmi Shili and Lotfi Ben Romdhane

Clustering method is one of the most important and basic technique for data mining which aims to group a collection of samples into clusters based on similarity. Clustering Big datasets has always been a serious challenge due to its high dimensionality and complexity. In this paper, we propose a novel clustering algorithm which aims to introduce the concept of intuitionistic fuzzy set theory onto the framework of CLARANS for handling uncertainty in the context of mining Big datasets. We also suggest a new scalable approximation to compute the maximum number of neighbors. Our experimental evaluation on real data sets shows that the proposed algorithm can obtain satisfactory clustering results

and outperforms other current methods. The clusters quality was evaluated by three well-known metrics.

Semi-supervised fuzzy c-means variants: a study on noisy label supervision

Violaine Antoine and Nicolas Labroche

Semi-supervised clustering algorithms aim at discovering the hidden structure of data sets with the help of expert knowledge, generally expressed as constraints on the data such as class labels or pairwise relations. Most of the time, the expert is considered as an oracle that only provides correct constraints. This paper focuses on the case where some label constraints are erroneous and proposes to investigate into more detail three semi-supervised fuzzy c-means clustering approaches as they have been tailored to naturally handle uncertainty in the expert labeling. In order to run a fair comparison between existing algorithms, formal improvements have been proposed to guarantee and fasten their convergence. Experiments conducted on real and synthetical datasets under uncertain labels and noise in the constraints show the effectiveness of using fuzzy clustering algorithm for noisy semi-supervised clustering.

Singular Outliers: Finding Common Observations with an Uncommon Feature

Mark Pijnenburg and Wojtek Kowalczyk

In this paper we introduce the concept of *singular outliers* and provide an algorithm (SODA) for detecting these outliers. Singular outliers are multivariate outliers that differ from conventional outliers by the fact that the anomalous values occur for only one feature (or a relatively small number of features). Singular outliers occur naturally in the fields of fraud detection and data quality, but can be observed in other application fields as well. The SODA algorithm is based on the local Euclidean Manhattan Ratio (LEMR). The algorithm is applied to five real-world data sets and the outliers found by it are qualitatively and quantitatively compared to outliers found by three conventional outlier detection algorithms, showing the different nature of singular outliers.

Operational Measurement of Data Quality

Antoon Bronselaer, Joachim Nielandt, Toon Boeckling and Guy De Tré

In this paper, an alternative view on measurement of data quality is proposed. Current procedures for data quality measurement provide information about the extent to which data misrepresent reality. These procedures are descriptive

in the sense that they provide us numerical information about the state of data. In many cases, this information is not sufficient to know whether data is fit for the task it was meant for. To bridge that gap, we propose a procedure that measures the operational characteristics of data. In this paper, we devise such a procedure by measuring the cost it takes to make data fit for use. We lay out the basics of this procedure and then provide more details on two essential components: tasks and transformation functions.

Randomness of Data Quality Artifacts

Toon Boeckling, Antoon Bronselaer and Guy De Tré

Quality of data is often measured by counting artifacts.
While this procedure is very simple and applicable to many different types of artifacts like errors, inconsistencies and missing values, counts do not differentiate between different distributions of data artifacts. A possible solution is to add a randomness measure to indicate how randomly data artifacts are distributed. It has been proposed to calculate randomness by means of the Lempel-Ziv complexity algorithm, this approach comes with some demerits. Most importantly, the Lempel-Ziv approach assumes that there is some implicit order among data objects and the measured randomness depends on this order. To overcome this problem, a new method is proposed which measures randomness proportionate to the average amount of bits needed to compress the bit matrix matching the artifacts in a database relation by using unary coding. It is shown that this method has several interesting properties that align the proposed measurement procedure with the intuitive perception of randomness.

Tag-based User Fuzzy Fingerprints for Recommender Systems

André Carvalho, Pável Calado and Joao Paulo Carvalho

Most Recommender Systems rely exclusively on ratings and are known as Memory-based Collaborative Filtering systems. This is currently dominant approach outside of academia due to the low implementation effort and service maintenance, when compared with more complex Model-based approaches, Traditional Memory-based systems have as their main goal to predict ratings, using similarity metrics to determine similarities between the users' (or items) rating patterns. In this work, we propose a user-based Collaborative Filtering approach based on tags that does not rely on rating prediction, instead leveraging on Fuzzy Fingerprints to create a novel similarity metric. Fuzzy Fingerprints provide a concise and compact representation of users allowing the reduction of the dimensionality usually associated with user-based collaborative filtering. The proposed recommendation strategy combined with the Fuzzy Fingerprint similarity metric is able to outperform our baselines, in the Movielens-1M dataset.

What is the aggregation of a partial metric and a quasi-metric?

Juan-José Miñana and Óscar Valero

Generalized metrics have been shown to be useful in many fields of Computer Science. In particular, partial metrics and quasi-metrics are used to develop quantitative mathematical models in denotational semantics and in asymptotic complexity analysis of algorithms, respectively. The aforesaid models are implemented independently and they are not related. However, it seems natural to consider a unique framework which remains valid for the applications to the both aforesaid fields. A first natural attempt to achieve that target suggests that the quantitative information should be obtained by means of the aggregation of a partial metric and a quasi-metric. Inspired by the preceding fact, we explore the way of merging, by means of a function, the aforementioned generalized metrics into a new one. We show that the induced generalized metric matches up with a partial quasi-metric. Thus, we characterize those functions that allow to generate partial quasi-metrics from the combination of a partial metric and a quasi-metric. Moreover, the relationship between the problem under consideration and the problems of merging partial metrics and quasi-metrics is discussed. Examples that illustrate the obtained results are also given.

Generalized Farlie-Gumbel-Morgenstern copulas

Anna Kolesárová, Radko Mesiar and Susanne Saminger-Platz

The Farlie-Gumbel-Morgenstern copulas are related to the independence copula Π and can be seen as perturbations of Π. Based on quadratic constructions of copulas, we provide a new look at them. Starting from any 2-dimensional copula and an appropriate real function, we introduce new parametric families of copulas which in the case of the independence copula Π coincide with the Farlie-Gumbel-Morgenstern family. Using the proposed approach, we also obtain as a particular case a subclass of the Fréchet family of copulas containing all three basic copulas W, Π and M, i.e. a comprehensive family of copulas. Finally, based on an iterative approach, we introduce copula families $(C_r)_{r\in[-\infty,\infty]}$ complete w.r.t. dependence parameters, resulting in the case of the independence copula and parameters $r \in [-1, 1]$ in the Farlie-Gumbel-Morgenstern family.

Metrics for Tag Cloud Evaluation

Úrsula Torres-Parejo, Jesús R. Campaña, María-Amparo Vila and Miguel Delgado

Since their appearance Tag Clouds are widely used tools in Internet. The main purposes of these textual visualizations are information retrieval, content representation and browsing of text. Despite their widespread use and the large

number of research that has been carried out on them, the main metrics available in the literature evaluate the quality of the tag cloud based only on the query results. There are no adequate metrics when the tag cloud is extracted from text and used to represent information content. In this work, three new metrics are proposed for the evaluation of tag clouds when their main function is to represent information content: coverage, overlap and disparity, as well as a fourth metric: the balance, in which we propose a way to calculate it by using OWA operators.

Uninorms that are neither conjunctive nor disjunctive on bounded lattices

Gül Deniz Çaylı

In this paper, we demonstrate that on some bounded lattices L, there exist elements $e \in L\backslash\{0,1\}$ such that all uninorms having e as the neutral element are only conjunctive or disjunctive. And we introduce two new construction methods to obtain uninorms that are neither conjunctive nor disjunctive on a bounded lattice with a neutral element under some additional constraints. Furthermore, an illustrative example showing that our methods differ slightly from each other is added.

An Efficient Gradual Three-way Decision Cluster Ensemble Approach

Hong Yu and Guoyin Wang

Cluster ensemble has emerged as a powerful technique for combining multiple clustering results. However, existing cluster ensemble approaches are usually restricted to two-way clustering, and they also cannot flexibility provide two-way or three-way clustering result accordingly. The main objective of this paper is to propose a general cluster ensemble framework for both two-way decision clustering and three-way decision. A cluster is represented by three regions such as the positive region, boundary region and negative region. The three-way representation intuitively shows which objects are fringe to the cluster. In this work, the number of ensemble members is increased gradually in each decision (iteration), it is different from the existing cluster ensemble methods in which all available ensemble members join the computing at one decision. It can be ended at a three-way decision final clusters or choose to go on until all the objects are assigned to the positive or negative region of the cluster determinately. The experimental results show that the proposed gradual three-way decision cluster ensemble approach is effective for reducing the running time and not sacrificing the accuracy.

Modes of Sequential Three-Way Classifications

Yiyu Yao, Mengjun Hu and Xiaofei Deng

We present a framework for studying sequential three-way classifications based on a sequence of description spaces and a sequence of evaluation functions. In each stage, a pair of a description space and an evaluation function is used for a three-way classification. A set of objects is classified into three regions. The positive region contains positive instances of a given class, the negative region contains negative instances, and the boundary region contains those objects that cannot be classified as positive or negative instances due to insufficient information. By using finer description spaces and finer evaluations, we may be able to make definite classifications for those objects in the boundary region in multiple steps, which gives a sequential three-way classification. We examine four particular modes of sequential three-way classifications with respect to multiple levels of granularity, probabilistic rough set theory, multiple models of classification, and ensemble classifications.

Determining Strategies in Game-theoretic Shadowed Sets

Yan Zhang and JingTao Yao

A three-way approximation of shadowed sets map the membership grades of all objects into a three-value set with a pair of thresholds. The game-theoretic shadowed sets (GTSS) determine and interpret a pair of thresholds of three-way approximations based on a principle of tradeoff with games. GTSS formulate competitive games between the elevation and reduction errors. The players start from the initial thresholds (1,0) and perform the certain strategies to change the thresholds in the game. The games are repeated with the updated thresholds to gradually reach the suitable thresholds. However, starting from a pair of randomly selected non-(1,0) thresholds is not examined in GTSS. We propose a game approach to make it possible for GTSS starting from a pair of randomly selected thresholds and then determine the strategies associated with them.

In particular, given a pair of randomly chosen initial thresholds, we use a game mechanism to determine the change directions that players prefer to make on the initial thresholds. The proposed approach supplements the GTSS, and can be added in the game formulation and repetition learning phases. We explain the game formulation, equilibrium analysis, and the determination of strategies in this paper. An example demonstrates how the proposed approach can supplement GTSS to obtain the thresholds of three-way approximations of shadowed sets when starting from randomly selected thresholds.

Three-way and Semi-Supervised Decision Tree Learning Based on Orthopartitions

Andrea Campagner and Davide Ciucci

Decision Tree Learning is one of the most popular machine learning techniques. A common problem with this approach is the inability to properly manage uncertainty and inconsistency in the underlying datasets. In this work we propose two generalized Decision Tree Learning models based on the notion of Orthopair: the first method allows the induced classifiers to abstain on certain instances, while the second one works with unlabeled outputs, thus enabling semi-supervised learning.

Towards an App based on FIWARE Architecture and Data Mining with Imperfect Data

José M. Cadenas, M. Carmen Garrido and Cristina Villa

In this work, the structure for the prototype construction of an application that can be framed within ubiquitous sensing is proposed. The objective of application is to allow that a user knows through his mobile device which other users of his environment are doing the same activity as him. Therefore, the knowledge is obtained from data acquired by pervasive sensors. The FIWARE infrastructure is used to allow to homogenize the data flows.

An important element of the application is the Intelligent Data Analysis module where, within the *Apache Storm* technology, a Data Mining technique will be used. This module identifies the activity carried out by mobile device user based on the values obtained by the different sensors of the device.

The Data Mining technique used in this module is an extension of the Nearest Neighbors technique. This extension allows the imperfect data processing, and therefore, the effort that must be made in the data preprocessing to obtain the minable view of data is reduced. It also allows us to parallelize part of the process by using the *Apache Storm* technology.

A Fuzzy Close Algorithm for Mining Fuzzy Association Rules

Régis Pierrard, Jean-Philippe Poli and Céline Hudelot

Association rules allow to mine large datasets to automatically discover relations between variables. In order to take into account both qualitative and quantitative variables, fuzzy logic has been applied and many association rule extraction algorithms have been fuzzified.

In this paper, we propose a fuzzy adaptation of the well-known Close algorithm which relies on the closure of itemsets. The Close-algorithm needs

less passes over the dataset and is suitable when variables are correlated. The algorithm is then compared to other on public datasets.

A 2D-approach towards the Detection of Distress using Fuzzy K-Nearest Neighbor

Daniel Machanje, Joseph Orero and Christophe Marsala

This paper focuses on a novel approach of distress detection referred to as the *2D approach*, using the fuzzy K-NN classification model. Unlike the traditional approach where single emotions were qualified to depict distress such as fear, anxiety, or anger, the 2D approach introduces two phases of classification, with the first one checking the speech excitement level, otherwise referred to as arousal in previous researches, and the second one checking the speech's polarity (negative or positive). Speech features are obtained from the Berlin Database of Emotional Studies (BDES), and feature selection done using the forward selection (FS) method. Attaining a distress detection accuracy of 86.64% using fuzzy K-NN, the proposed 2D approach shows promise in enhancing the detection of emotional states having at least two emotions that could qualify the emotion in question based on their original descriptions just as distress can be either one or many of a number of emotions. Application areas for distress detection include health and security for hostage scenario detection and faster medical response respectively.

Datil: Learning Fuzzy Ontology Datatypes

Ignacio Huitzil, Umberto Straccia, Natalia Díaz-Rodríguez and Fernando Bobillo

Real-world applications using fuzzy ontologies are increasing in the last years, but the problem of fuzzy ontology learning has not received a lot of attention. While most of the previous approaches focus on the problem of learning fuzzy subclass axioms, we focus on learning fuzzy datatypes. In particular, we describe the *Datil* system, an implementation using unsupervised clustering algorithms to automatically obtain fuzzy datatypes from different input formats. We also illustrate the practical usefulness with an application: semantic lifestyle profiling.

Modelling Medical Uncertainties with Use of Fuzzy Sets and Their Extensions

Patryk Żywica

This work presents an approach to deal with uncertainty in patient's medical record. After giving a brief characterisation of possible sources of uncertainty in medical records, the paper introduces fuzzy set based approach that allows modelling of such information. First, heterogeneous data is converted to homogeneous model with the use of Feature Set structure. With such model uncertainty may be represented directly as Fuzzy Membership Function Families (FMFFs). Some theoretical results connecting FMFFs with Hesitant Fuzzy Sets and Type-2 Fuzzy Sets are also given.

An uncertainty aware medical diagnosis support system

Krzysztof Dyczkowski, Anna Stachowiak, Andrzej Wójtowicz and Patryk Żywica

In the paper we describe a computer system that store and process uncertain data in such a way as to be able to obtain information essential to make an effective diagnosis while also indicating the uncertainty level of that diagnosis. We consider the problem of incompleteness and imprecision of medical data and discuss some issues connected with such kind of information - like modeling, making decision that is aware of the imperfection of data, evaluating results in the context of uncertain medical data. As an example we describe a method of supporting medical decision implemented in the OvaExpert system that is based on interval-valued fuzzy sets cardinality.

Diverse classes of interval-valued aggregation functions in medical diagnosis support

Urszula Bentkowska and Barbara Pękala

In this contribution results connected with using new types of aggregation functions in medical diagnosis support are presented. These aggregation functions belong to the recently introduced families of possible and necessary aggregation functions as well as aggregation functions with respect to admissible linear orders. Examples of the mentioned families of aggregation functions proved to be comparably effective (if it comes to statistical measures and lower cost of prediction) to the previously used aggregation functions in medical diagnosis support systems. The considered classes of aggregation functions differ from the ones previously applied by the comparability relations between intervals involved in the monotonicity conditions.

On Fuzzy Compliance for Clinical Protocols

Anna Wilbik, Ivo Kuiper, Walther van Mook, Dennis Bergmans, Serge Heines and Irene Vanderfeesten

Clinical protocols are introduced in hospitals to standardize the care delivery process. Compliance is a measure used to determine whether the protocol has been followed. However, so far an activity in the protocol could be either compliant or non-compliant. In this paper we consider the compliance of a single activity as a fuzzy term. We propose to define the rules which can assess the compliance degree of an activity. We proposed the fuzzy compliance measure of clinical protocol that aggregates those compliance degrees. We demonstrate a case of glucose management protocol at Intensive Care Unit (ICU). Initial results are promising.

Forecasting energy demand by clustering smart metering time series

Christian Bock

Current demands on the energy market, such as legal policies towards green energy usage and economic pressure due to growing competition, require energy companies to increase their understanding of consumer behavior and streamline business processes. One way to help achieve these goals is by making use of the increasing availability of *smart metering time series*. In this paper we extend an approach based on *fuzzy clustering* using smart meter data to yield *load profiles* which can be used to forecast the energy demand of customers. In addition, our approach is built with existing business processes in mind. This helps not only to accurately satisfy real world requirements, but also to ease adoption by the industry. We also assess the quality of our approach using real world smart metering datasets.

Linguistic description of the evolution of stress level using fuzzy deformable prototypes

Francisco P. Romero, José A. Olivas and Jesús Serrano-Guerrero

The purpose of this paper is to show that it is possible to describe stress levels through a complete time-log analysis. For this purpose it has been developed a fuzzy deformable prototypes based model that uses a fuzzy representation of the prototypical situations. The proposed model has been applied to a database composed of time logs from students with and without stress. Preliminary results from the proposed model application have been validated by experts. Moreover, the model has been applied as a classifier obtaining good results for both sensitivity and specificity. Finally, the proposal has been validated and

should be considered useful for the expert systems design to support the stress level description.

Model averaging approach to forecasting the general level of mortality

Marcin Bartkowiak, Katarzyna Kaczmarek-Majer, Aleksandra Rutkowska and Olgierd Hryniewicz

Already a 1% improvement to the overall forecast accuracy of mortality rates, may lead to the significant decrease of insurers costs. In practice, Lee-Carter model is widely used for forecasting the mortality rates. Within this study, we combine the traditional Lee-Carter model with the recent advances in the weighted model averaging. For this purpose, first, the training database of template predictive models is constructed for the mortality data and processed with similarity measures, and secondly, competitive predictive models are averaged to produce forecasts. The main innovation of the proposed approach is reflecting the uncertainty related to the shortness (e.g., 14 observations) of available data by the incorporation of multiple predictive models. The performance of the proposed approach is illustrated with experiments for the Human Mortality Database. We analyzed time series datasets for women and men aged 0-100 years from 10 countries in the Central and Eastern Europe. The presented numerical results seem very promising and show that the proposed approach is highly competitive with the state-of-the-art models. It outperforms benchmarks especially when forecasting long periods (6-10 years ahead).

Similarity-Based Accuracy Measures for Approximate Query Results

Agnieszka Chądzyńska-Krasowska

We introduce a new approach to empirical evaluation of the accuracy of the select statement results produced by a relational approximate query engine. We emphasize the meaning of a similarity of approximate and exact outcomes of queries from the perspective of practical applicability of approximate query processing solutions. We propose how to design the similarity-based procedure that lets us compare approximate and exact versions of the results of complex queries. We not only offer a measure of the accuracy of query results, but also describe the results of research on users intuition regarding the properties of such a measure, as well as perception query results as similar. The study is supported by theoretical and empirical analyses of different similarity functions and the case study of the investigative analytics over data sets related to network intrusion detection.

Object [Re]Cognition with Similarity

Łukasz Sosnowski and Julian Skirzyński

We discuss the origin of the notion of similarity, basic concepts connected with it and some methods of representing this conception in mathematical setting. We present a framework of recognition that is based on multi-aspects similarity. The framework is implemented in form of a network of comparators, that processes similarity expressed in terms of fuzzy sets. Our approach introduces a new standard to the field of similarity computing and processing.

How to Match Jobs and Candidates - A Recruitment Support System Based on Feature Engineering and Advanced Analytics

Andrzej Janusz, Sebastian Stawicki, Michał Drewniak, Krzysztof Ciebiera, Dominik Ślęzak and Krzysztof Stencel

We describe a recruitment support system aiming to help recruiters in finding candidates who are likely to be interested in a given job offer. We present the architecture of that system and explain roles of its main modules. We also give examples of analytical processes supported by the system. In the paper, we focus on a data processing chain that utilizes domain knowledge for the extraction of meaningful features representing pairs of candidates and offers. Moreover, we discuss the usage of a word2vec model for finding concise vector representations of the offers, based on their short textual descriptions. Finally, we present results of an empirical evaluation of our system.

On the structure of acyclic binary relations

José C. R. Alcantud, María J. Campión, Juan C. Candeal, Raquel G. Catalán and Esteban Induráin

We investigate the structure of acyclic binary relations from different points of view. On the one hand, given a nonempty set we study real-valued bivariate maps that satisfy suitable functional equations, in a way that their associated binary relation is acyclic. On the other hand, we consider acyclic directed graphs as well as their representation by means of incidence matrices. Acyclic binary relations can be extended to the asymmetric part of a linear order, so that, in particular, any directed acyclic graph has a topological sorting.

Extracting Decision Rules from Qualitative Data via Sugeno Utility Functionals

Quentin Brabant, Miguel Couceiro, Didier Dubois, Henri Prade and Agnès Rico

Sugeno integrals are qualitative aggregation functions. They are used in multiple criteria decision making and decision under uncertainty, for computing global evaluations of items, based on local evaluations. The combination of a Sugeno integral with unary order preserving functions on each criterion is called a Sugeno utility functionals (SUF). A noteworthy property of SUFs is that they represent multi-threshold decision rules, while Sugeno integrals represent single-threshold ones. However, not all sets of multi-threshold rules can be represented by a single SUF. In this paper, we consider functions defined as the minimum or the maximum of several SUFs. These max-SUFs and min-SUFs can represent all functions that can be described by a set of multi-threshold rules, i.e., all order-preserving functions on finite scales. We study their potential advantages as a compact representation of a big set of rules, as well as an intermediary step for extracting rules from empirical datasets.

An IoT Control System for wind power generators

Marouane Salhaoui, Mounir Arioua, Antonio Guerrero-González and M. Socorro García-Cascales

New technology deployment for facilitating the control and managing huge amount of data and its uncertainty is very important challenge in the industry field. Energy sector as important part of the industry knows nowadays a high transformation towards renewable energy, and one of important solution is the wind energy. The wind control system must guarantee safe and reliable operation, monitor components and variables, and check that these variables are in an admissible range and must perform the detection and prediction of faults. We propose in this paper a new Internet of Things solution to control and monitor a wind energy system. The IoT gateway is used as a bridge between the different devices in the wind turbine control system and Internet. We adopted OPC Unified Architecture, as a protocol of communication, and we implemented the new IoT tool Node-RED in the gateway, in order to facilitate the link between OPC UA client and IBM cloud. The obtained results are evaluated in real-time in the cloud platform which eventually provides a consistent analysis and interpretation, and making better decision.

On the migrativity property for uninorms and nullnorms

Emel Aşıcı

In this paper the notions of α-migrative uninorms over a fixed nullnorm and α-migrative nullnorms over a fixed uninorm are introduced and studied. All solutions of the migrativity equation for all possible combinations of uninorms and nullnorms are investigated. So, (α, T)-migrative nullnorm and (α, T)-migrative uninorm (α, S)-migrative nullnorm and (α, S)-migrative uninorm) for a given t-norm (t-conorm) are extended to a more general form.

Comparison of Fuzzy Integral-Fuzzy Measure based Ensemble Algorithms with the State-of-the-art Ensemble Algorithms

Utkarsh Agrawal, Anthony J. Pinar, Christian Wagner, Timothy C. Havens, Daniele Soria and Jonathan M. Garibaldi

The Fuzzy Integral (FI) is a non-linear aggregation operator which enables the fusion of information from multiple sources in respect to a Fuzzy Measure (FM) which captures the worth of both the individual sources and all their possible combinations. Based on the expected potential of non-linear aggregation offered by the FI, its application to decision-level fusion in ensemble classifiers, i.e. to fuse multiple classifiers outputs towards one superior decision level output, has recently been explored. A key example of such a FI-FM ensemble classification method is the Decision-level Fuzzy Integral Multiple Kernel Learning (DeFIMKL) algorithm, which aggregates the outputs of kernel based classifiers through the use of the Choquet FI with respect to a FM learned through a regularised quadratic programming approach. While the approach has been validated against a number of classifiers based on multiple kernel learning, it has thus far not been compared to the state-of-the-art in ensemble classification. Thus, this paper puts forward a detailed comparison of FI-FM based ensemble methods, specifically the DeFIMKL algorithm, with state-of-the art ensemble methods including Adaboost, Bagging, Random Forest and Majority Voting over 20 public datasets from the UCI machine learning repository. The results on the selected datasets suggest that the FI based ensemble classifier performs both well and efficiently, indicating that it is a viable alternative when selecting ensemble classifiers and indicating that the non-linear fusion of decision level outputs offered by the FI provides expected potential and warrants further study.

Application of Aggregation Operators to Assess the Credibility of User-Generated Content in Social Media

Gabriella Pasi and Marco Viviani

Nowadays, User-Generated Content (UGC) spreads across social media through Web 2.0 technologies, in the absence of traditional trusted third parties that can verify its credibility. The issue of assessing the credibility of UGC is a recent research topic, which has been tackled by many approaches as a classification problem: information is automatically categorized into genuine and fake, usually by employing data-driven solutions, based on Machine Learning (ML) techniques. In this paper, to address some open issues concerning the use of ML, and to give to the decision maker a major control on the process of UGC credibility assessment, the importance that the Multi-Criteria Decision Making (MCDM) paradigm can have in association with the use of aggregation operators is discussed. Some potential aggregation schemes and their properties are illustrated, as well as some interesting research directions.

Obtaining WAPO-Structure through Inverted Indexes

Úrsula Torres-Parejo, Jesús R. Campaña, María-Amparo Vila and Miguel Delgado

In order to represent texts preserving their semantics, in earlier work we proposed the WAPO-Structure, which is an intermediate form of representation that allows related terms to remain together. This intermediate form can be visualized through a tag cloud, which in turn serves as a textual navigation and retrieval tool. WAPO-Structures were obtained through a modification of the APriori algorithm, which spends a lot of processing time computing frequent sequences, for which it must perform numerous readings on the text until finding the frequent sequences of maximal level.
In this paper we present an alternative method for the generation of the WAPO-Structure from the inverted indexes of the text. This method saves processing time in texts for which an inverted index is already computed.

Automatic Expansion of Spatial Ontologies for Geographic Information Retrieval

Manuel E. Puebla-Martínez, José M. Perea-Ortega, Alfredo Simón-Cuevas and Francisco P. Romero

One of the most prominent scenarios for capturing implicit knowledge from heterogeneous data sources concerns the geospatial data domain. In this scenario, ontologies play a key role for managing the totality of geospatial concepts, categories and relations at different resolutions. However, the manual development of geographic ontologies implies an exhausting work due to the rapid growth of the data available on the Internet. In order to address this challenge, the present work describes a semi-automatic approach to build and expand a geographic ontology by integrating the information provided by diverse spatial data sources. The generated ontology can be used as a knowledge resource in a Geographic Information Retrieval system. As a main novelty, the use of OWL 2 as an ontology language allowed us to model and infer new spatial relationships, regarding the use of other less expressive languages such as RDF or OWL 1. Two different spatial ontologies were generated for two specific geographic regions by applying the proposed approach, and the evaluation results showed their suitability to be used as geographic-knowledge resources in Geographic Information Retrieval contexts.

Increasing Performance via Gamification in a Volunteer-Based Evolutionary Computation System

Mario García-Valdéz, Juan J. Merelo-Guervós, Lucero Lara and Pablo García-Sánchez

Distributed computing systems can be created using volunteers, users who spontaneously, after receiving an invitation, decide to provide their own resources or storage to contribute to a common effort. They can, for instance, run a script embedded in a web page; thus, collaboration is straightforward, but also ephemeral, with resources depending on the amount of time the user decides to lend. This implies that the user has to be kept engaged so as to obtain as many computing cycles as possible. In this paper, we analyze a volunteer-based evolutionary computing system called NodIO with the objective of discovering design decisions that encourage volunteer participation, thus increasing the overall computing power. We present the results of an experiment in which a gamification technique is applied by adding a leader-board showing the top scores achieved by registered contributors. In NodIO, volunteers can participate without creating an account, so one of the questions we wanted to address was if the need to register would have a negative impact on user participation. The experiment results show that even if only a small percentage of users created

an account, those participating in the competition provided around 90% of the work, thus effectively increasing the performance of the overall system.

Using syntactic analysis to enhance aspect based sentiment analysis

Juan Moreno-García and Jesús Rosado

Many companies/corporations are interested in the opinion that users share about them in different social media. Sentiment analysis provides us with a powerful tool to discern the polarity of the opinion about a particular object or service, which makes it an important research field nowadays. In this paper we present a method to perform the sentiment analysis of a sentence through its syntactic analysis, by generating a code in *Prolog* from the parse tree of the sentence, which is automatically generated using natural language processing tools. This is a preliminary work, which provides encouraging results.

A probabilistic author-centered model for Twitter discussions

Teresa Alsinet, Josep Argelich, Ramón Béjar, Francesc Esteva and Lluís Godo

In a recent work some of the authors have developed an argumentative approach for discovering relevant opinions in Twitter discussions with probabilistic valued relationships. Given a Twitter discussion, the system builds an argument graph where each node denotes a tweet and each edge denotes a criticism relationship between a pair of tweets of the discussion. Relationships between tweets are associated with a probability value, indicating the uncertainty on whether they actually hold. In this work we introduce and investigate a natural extension of the representation model, referred as probabilistic author-centered model. In this model, tweets by a same author are grouped, describing his/her opinion in the discussion, and are represented with a single node in the graph, while edges stand for criticism relationships between author's opinions. In this new model, interactions between authors can give rise to circular criticism relationships, and the probability of one opinion criticizing another is evaluated from the criticism probabilities among the individual tweets in both opinions.

A concept-based text analysis approach using knowledge graph

Wenny Hojas-Mazo, Alfredo Simón-Cuevas, Manuel De la Iglesia Campos, Francisco P. Romero and José A. Olivas

The large amounts and growing of unstructured texts, available in Internet and other scenarios, are becoming a very valuable resource of information and knowledge. The present work describes a concept-based text analysis approach, based on the use of a knowledge graph for structuring the texts content and a query language for retrieving relevant information and obtaining knowledge from the knowledge graph automatically generated. In the querying process, a semantic analysis method is applied for searching and integrating the conceptual structures from the knowledge graph, which is supported by a disambiguation algorithm and WordNet. The applicability of the proposed approach was evaluated in the analysis of scientific articles from a Systematic Literature Review and the results were contrasted with the conclusions obtained by the authors of this review.

Defuzzyfication in Interpretation of Comparator Networks

Łukasz Sosnowski and Marcin Szczuka

We present an extension to the methods and algorithms for approximation of similarity known as Networks of Comparators. By interpreting the output of the network in terms of discrete fuzzy set we make it possible to employ various defuzzyfication techniques for the purpose of establishing a unique value of the output of comparator network. We illustrate the advantages of this approach using two examples.

A Comparison of Characteristic Sets and Generalized Maximal Consistent Blocks in Mining Incomplete Data

Patrick G. Clark, Cheng Gao, Jerzy W. Grzymala-Busse and Teresa Mroczek

We discuss two interpretations of missing attribute values, lost values and "do not care" conditions. Both interpretations may be used for data mining based on characteristic sets. On the other hand, maximal consistent blocks were originally defined for incomplete data sets with "do not care" conditions, using only lower and upper approximations. We extended definitions of maximal consistent blocks to both interpretations while using probabilistic approximations, a generalization of lower and upper approximations. Our main objective is to

compare approximations based on characteristic sets with approximations based on maximal consistent blocks in terms of an error rate.

Rules Induced from Rough Sets in Information Tables with Continuous Values

Michinori Nakata, Hiroshi Sakai and Keitarou Hara

Rule induction based on neighborhood rough sets is described in information tables with continuous values. An indiscernible range that a value has in an attribute is determined by a threshold on that attribute. The indiscernibility relation is derived from using the indiscernible range. First, lower and upper approximations are described in complete information tables by directly using the indiscernibility relation. Rules are obtained from the approximations. To improve the applicability of rules, a series of rules is put into one rule expressed with an interval value, which is called a combined rule. Second, these are addressed in incomplete information tables. Incomplete information is expressed by a set of values or an interval value. The indiscernibility relations are constructed from two viewpoints: certainty and possibility. Consequently, we obtain four types of approximations: certain lower, certain upper, possible lower, and possible upper approximations. Using these approximations, rough sets are expressed by interval sets. From these approximations we obtain four types of combined rules: certain and consistent, certain and inconsistent, possible and consistent, and possible and inconsistent ones. These combined rules have greater applicability than single rules that individual objects support.

A Linear Model for Three-Way Analysis of Facial Similarity

Daryl H. Hepting, Hadeel Hatim Bin Amer and Yiyu Yao

Card sorting was used to gather information about facial similarity judgments. A group of raters put a set of facial photos into an unrestricted number of different piles according to each rater's judgment of similarity. This paper proposes a linear model for 3-way analysis of similarity. An overall rating function is a weighted linear combination of ratings from individual raters. A pair of photos is considered to be similar, dissimilar, or divided, respectively, if the overall rating function is greater than or equal to a certain threshold, is less than or equal to another threshold, or is between the two thresholds. The proposed framework for 3-way analysis of similarity is complementary to studies of similarity based on features of photos.

Empirical Comparison of Distances for Agglomerative Hierarchical Clustering

Shusaku Tsumoto

This paper proposes a method for empirical comparison of distances for agglomerative hierarchical clustering based on rough set-based approximation. When a set of target is given, a level of clustering tree where one branch includes all the targets can be traced with the number of elements included. The pair $(\#clustersofalevel, \#elementsofacluster)$ can be viewed as indices-pair for a given clustering tree.

Attribute Reduction of Set-valued Decision Information System

Jun Hu, Siyu Huang and Rui Shao

In practice, we may obtain data which is set-valued due to the limitation of acquisition means or the requirement of practical problems. In this paper, we focus on how to reduce set-valued decision information systems under the disjunctive semantics. First, a new relation to measure the degree of similarity between two set-valued objects is defined, which overcomes the limitations of the existing measure methods. Second, an attribute reduction algorithm for set-valued decision information systems is proposed. At last, the experimental results demonstrate that the proposed method can simplify set-valued decision information systems and achieve higher classification accuracy than existing methods.

Ideal and Real Party Positions in the 2015-2016 Spanish General Elections

M.D. García-Sanz, I. Llamazares and M.A. Manrique

In this paper, using data from the pre-electoral and post-electoral Spanish surveys conducted by the Centro de Investigaciones Sociológicas (CIS) in the 2015 and 2016 general elections and assuming that parties maximize votes, we use an iterative algorithm to derive the optimal party positions (as predicted by spatial competition models based on proximity and directional models of voting). These optimal policy positions constitute a Nash equilibria, in which no party can increase its vote share by changing unilaterally its policy position. Then we compare the actual ideological positions of Spanish parties (as perceived by all voters) to their ideological party positions. Our aims are to examine the predictive power of proximity and directional models in the two Spanish electoral processes, to explore the degree to which parties deviate from their ideal

positions and to examine the evolution of party positions from December 2015 to June 2016.

DNBMA: A Double Normalization-Based Multi-Aggregation Method

Huchang Liao, Xingli Wu and Francisco Herrera

We propose a double normalization-based multi-aggregation method to deal with the multi-criteria decision making problems considering the benefit, cost and target criterion values. To do so, we introduce an enhanced target-based linear normalization formula and a target-based vector normalization formula. Given that different normalization techniques maintain special advantages and disadvantages, we combine them with three aggregation models to describe the alternatives' performance from different aspects. Then, a new integration approach is developed to integrate three types of subordinate utility values and ranks to derive the final ranking. The selected alternative not only has a comprehensive performance but does not perform badly under each criterion. Finally, the proposed method is highlighted by a case study of selecting an optimal innovation enterprise.

Design of a Decision Support System for Buried Pipeline Corrosion Assessment

Laurence Boudet, Jean-Philippe Poli, Alicia Bel, François Castillon, Frédéric Gaigne and Olivier Casula

Maintaining the level of integrity of pipeline networks to guarantee at least a reliable and safe service is a challenge operators of such networks are facing everyday. TIGF is one of the French operator which manages 5000km of pipelines in the south-west quarter of France. This paper presents a decision-making tool which automatically ranks the pipeline sections regarding the risk of deterioration (damages and corrosion) and the gravity of the consequences, indicating which pipeline sections should be excavated. The tool relies on a fuzzy expert system which gathers 26 input variables, processes more than 300 rules, classifies the risk of deterioration into 7 classes and estimates the gravity. The rules are a formalization of human expertise: the fuzzy logic helps to tackle the vagueness of their knowledge and the measurement inaccuracy of some of the 26 input variables. The method has been tested on past excavations to assess its performances.

How Potential BLFs Can Help to Decide under Incomplete Knowledge

Florence Dupin de Saint-Cyr and Romain Guillaume

In a Bipolar Leveled Framework (BLF), the comparison of two candidates is done on the basis of the decision principles and inhibitions which are validated given the available knowledge-bases associated with each candidate. This article defines a refinement of the rules for comparing candidates by using the potential-BLFs which can be built according to what could additionally be learned about the candidates. We also propose a strategy for selecting the knowledge to acquire in order to better discriminate between candidates.

Sequential decision making under uncertainty: ordinal uninorms vs. the Hurwicz criterion

Hélène Fargier and Romain Guillaume

This paper focuses on sequential decision problems under uncertainty, i.e. sequential problems where no probability distribution on the states that may follow an action is available. New qualitative criteria are proposed that are based on ordinal uninorms, namely R_* and R^*. Like the Hurwicz criterion, the R_* and R^* uninorms arbitrate between pure pessimism and pure optimism, and generalize the Maximin and Maximax criteria. But contrarily to the Hurwicz criterion they are associative, purely ordinal and compatible with *Dynamic Consistency* and *Consequentialism*. This latter important property allow the construction of an optimal strategy in polytime, following an algorithm of Dynamic Programming.

A proposal to measure human group behaviour stability

Teresa González-Arteaga, José Manuel Cascón and Rocío de Andrés

A non-traditional approach on the measurement of agents' behaviour is presented. This contribution focus on measuring stability of agents' preferences on an intertemporal context under the assumption of considering uncertainty opinions. To this aim, the concept of behaviour stability measure is defined as well as a particular one, the sequential behaviour stability measure. Finally and in order to highlight the good behaviour of novel measure, some properties are also provided.

The median procedure as an example of penalty-based aggregation of binary relations

Raúl Pérez-Fernández and Bernard De Baets

The aggregation of binary relations is a common topic in many fields of application such as social choice and cluster analysis. In this paper, we discuss how the median procedure – probably the most common method for aggregating binary relations – fits in the framework of penalty-based data aggregation.

Least median of squares (LMS) and least trimmed squares (LTS) fitting for the weighted arithmetic mean

Gleb Beliakov, Marek Gagolewski and Simon James

We look at different approaches to learning the weights of the weighted arithmetic mean such that the median residual or sum of the smallest half of squared residuals is minimized. The more general problem of multivariate regression has been well studied in statistical literature, however in the case of aggregation functions we have the restriction on the weights and the domain is also usually restricted so that 'outliers' may not be arbitrarily large. A number of algorithms are compared in terms of accuracy and speed. Our results can be extended to other aggregation functions.

Combining absolute and relative information in studies on food quality

Marc Sader, Raúl Pérez-Fernández and Bernard De Baets

A common problem in food science concerns the assessment of the quality of food samples. Typically, a group of panellists is trained exhaustively on how to identify different quality indicators in order to provide absolute information, in the form of scores, for each given food sample. Unfortunately, this training is expensive and time-consuming. For this very reason, it is quite common to search for additional information provided by untrained panellists. However, untrained panellists usually provide relative information, in the form of rankings, for the food samples. In this paper, we discuss how both scores and rankings can be combined in order to improve the quality of the assessment.

Robust On-Line Streaming Clustering

Omar Ibrahim, Yizhuo Du and James Keller

With the explosion of ubiquitous continuous sensing, on-line streaming clustering continues to attract attention. The requirements are that the streaming clustering algorithm recognize and adapt clusters as the data evolves, that anomalies are detected, and that new clusters are automatically formed as incoming data dictate. In this paper, we extend an earlier approach, called Extended Robust On-Line Streaming Clustering (EROLSC), which utilizes both the Possibilistic C-Means and Gaussian Mixture Decomposition to perform this task. We show the superiority of EROLSC over traditional streaming clustering algorithms on synthetic and real data sets.

Twofold binary image consensus for medical imaging meta-analysis

Carlos López-Molina, Javier Sánchez Ruiz de Gordoa, M. Victoria Zelaya-Huerta and Bernard De Baets

In the field of medical imaging, ground truth is often gathered from groups of experts, whose outputs are generally heterogeneous. This procedure raises questions on how to compare the results obtained by automatic algorithms to multiple ground truth items. Secondarily, it raises questions on the meaning of the divergences between experts. In this work, we focus on the case of immunohistochemistry image segmentation and analysis. We propose measures to quantify the divergence in groups of ground truth images, and we observe their behaviour. These measures are based upon fusion techniques for binary images, which is a common example of non-monotone data fusion process. Our measures can be used not only in this specific field of medical imagery, but also in any task related to meta-quality evaluation for image processing, e.g. ground truth validation or expert rating.

Penalty-based functions defined by pre-aggregation functions

Graçaliz Pereira Dimuro, Radko Mesiar, Humberto Bustince, Benjamín Bedregal, José Antonio Sanz and Giancarlo Lucca

Pre-aggregation function (PAF) is an important concept that has emerged in the context of directional monotonicity functions. Such functions satisfy the same boundary conditions of an aggregation functions, but it is not required the monotone increasingness in all the domain, just in some fixed directions. On the other hand, penalty functions is another important concept for decision making applications, since they can provide a measure of deviation from the consensus

value given by averaging aggregation functions, or a penalty for not having such consensus. This paper studies penalty-based functions defined by PAFs. We analyse some properties (e.g: idempotency, averaging behavior and shift-invariance), providing a characterization of idempotent penalty-based PAFs and a weak characterization of averaging penalty-based PAFs. The use of penalty-based PAFs in spatial/tonal filters is outlined.

Strengthened ordered directional and other generalizations of monotonicity for aggregation functions

Mikel Sesma-Sara, Laura De Miguel, Julio Lafuente, Edurne Barrenechea, Radko Mesiar and Humberto Bustince

A tendency in the theory of aggregation functions is the generalization of the monotonicity condition. In this work, we examine the latest developments in terms of different generalizations. In particular, we discuss strengthened ordered directional monotonicity, its relation to other types of monotonicity, such as directional and ordered directional monotonicity and the main properties of the class of functions that are strengthened ordered directionally monotone. We also study some construction methods for such functions and provide a characterization of usual monotonicity in terms of these notions of monotonicity.

A study of different families of fusion functions for combining classifiers in the One-vs-One strategy

Mikel Uriz, Daniel Paternain, Aranzazu Jurio, Humberto Bustince and Mikel Galar

In this work we study the usage of different families of fusion functions for combining classifiers in a multiple classifier system of *One-vs-One* (OVO) classifiers. OVO is a decomposition strategy used to deal with multi-class classification problems, where the original multi-class problem is divided into as many problems as pair of classes. In a multiple classifier system, classifiers coming from different paradigms such as support vector machines, rule induction algorithms or decision trees are combined. In the literature, several works have addressed the usage of classifier selection methods for these kinds of systems, where the best classifier for each pair of classes is selected. In this work, we look at the problem from a different perspective aiming at analyzing the behavior of different families of fusion functions to combine the classifiers. In fact, a multiple classifier system of OVO classifiers can be seen as a multi-expert decision making problem. In this context, for the fusion functions depending on weights or

fuzzy measures, we propose to obtain these parameters from data. Backed-up by a thorough experimental analysis we show that the fusion function to be considered is a key factor in the system. Moreover, those based on weights or fuzzy measures can allow one to better model the aggregation problem.

Aggregation functions based on deviations

Marián Decký, Radko Mesiar and Andrea Stupňanová

After recalling penalty and deviation based constructions of idempotent aggregation functions, we introduce the concept of a general deviation function and related construction of aggregation functions. Our approach is exemplified in some examples, illustrating the ability of our method to model possibly different aggregation attitudes in different coordinates of the aggregated score vectors.

Image feature extraction using OD-monotone functions

Cedric Marco-Detchart, Carlos López-Molina, Javier Fernández, Miguel Pagola and Humberto Bustince

Edge detection is a basic technique used as a preliminary step for, e.g., object extraction and recognition in image processing. Many of the methods for edge detection can be fit in the breakdown structure by Bezdek, in which one of the key parts is feature extraction. This work presents a method to extract edge features from a grayscale image using the so-called ordered directionally monotone functions. For this purpose we introduce some concepts about directional monotonicity and present two construction methods for feature extraction operators. The proposed technique is competitive with the existing methods in the literature. Furthermore, if we combine the features obtained by different methods using penalty functions, the results are equal or better results than state-of-the-art methods.

Interval Type-2 Intuitionistic Fuzzy Logic Systems - A Comparative Evaluation

Imo Eyoh, Robert John and Geert De Maere

Several fuzzy modeling techniques have been employed for handling uncertainties in data. This study presents a comparative evaluation of a new class of interval type-2 fuzzy logic system (IT2FLS) namely: interval type-2 intuitionistic fuzzy logic system (IT2IFLS) of Takagi-Sugeno-Kang (TSK)-type with classical IT2FLS and its type-1 variant (IFLS). Simulations are conducted using a

real-world gas compression system (GCS) dataset. Study shows that the performance of the proposed framework with membership functions (MFs) and non-membership functions (NMFs) that are each intervals is superior to classical IT2FLS with only MFs (upper and lower) and IFLS with MFs and NMFs that are not intervals in this problem domain.

Merging information using Uncertain Gates: An application to Educational Indicators

Guillaume Petiot

Knowledge provided by human experts is often imprecise and uncertain. The possibility theory provides a solution to handle these problems. The modeling of knowledge can be performed by a possibilistic network but demands to define all the parameters of Conditional Possibility Tables. Uncertain gates allow us, as noisy gates in probability theory, the automatic calculation of Conditional Possibility Tables. The uncertain gates connectors can be used for merging information. We can use the T-norm, T-conorm, mean, and hybrid operators to define new uncertain gates connectors. In this paper, we will present an experimentation on the calculation of educational indicators. Indeed, the LMS Moodle provides a large scale of data about learners that can be merged to provide indicators to teachers. Therefore, teachers can better understand their students' needs and how they learn. The knowledge about the behavior of learners can be provided by teachers but also by the process of datamining. The knowledge is modeled by using uncertain gates and evaluated from the data. The indicators can be presented to teachers in a decision support system.

New negations on the type-2 membership degrees

Carmen Torres-Blanc, Susana Cubillo and Pablo Hernández-Varela

P. Hernandez et al. [9] established the axioms that an operation must fulfill in order to be a negation on a bounded poset (partially ordered set), and they also established in [14] the conditions that an operation must satisfy to be an aggregation operator on a bounded poset. In this work, we focus on the set of the membership degrees of the type-2 fuzzy sets, and therefore, the set $\mathbf{M}$ of functions from [0,1] to [0,1]. In this sense, the negations on $\mathbf{M}$ respect to each of the two partial orders defined in this set are presented for the first time. In addition, the authors show new negations on $\mathbf{L}$ (set of the normal and convex functions of $\mathbf{M}$) that are different from the negations presented in [9] applying the Zadeh's Extension Principle. In particular, negations on $\mathbf{M}$ and on $\mathbf{L}$ are obtained from aggregation operators and negations. As results to highlight, a characterization of the strong negations that leave the constant function 1 fixed is given, and a new family of strong negations on $\mathbf{L}$ is presented.

Combining Weighted Description Logic with Fuzzy Logic for Decision Making

Nadine Mueller, Klemens Schnattinger and Heike Walterscheid

In this paper we present a consensus-theoretic framework based on weighted description logic and on a consensus modelling approach, which is used to retrieve a consistent decision among experts along multi-attributes. We will show that the integration of these two approaches is best suited for consensus building between (human) experts, especially when their preferences are not easily found or disturbed by coincidental influences. As an application of our methodology, we interviewed experts (in our case students) on the choice of means of transport. One time we asked them directly about their preferences and another time we asked them about their attitudes towards ecology, economy, and others. We will show how these two approaches of gathering data lead to different constructed hypothetical consensus and how the additional use of weighted description logic reveals other diverse insights. Our consensus-theoretical methodology begins with the modelling of basic attribute characteristics, mapping them into fuzzy preference relations and thus supports the decision-making process with respect to consensus.

On Hash Bipolar Division: An Enhanced Processing of Novel and Conventional Forms of Bipolar Division

Noussaiba Benadjimi, Walid-Khaled Hidouci and Allel Hadjali

In this paper, two issues of bipolar division are discussed. First, we outline some new operators dealing with the bipolar division, to enrich the interpretations of bipolar queries. In this context, we propose some extended operators of bipolar division based on the connector “or else". Besides, we introduce a new bipolar division operator dealing with the “Satisfied-Dissatisfied approach". Secondly, we highlight the matter of the performance improvement of the considered operators. Thus, we present an efficient method which allows handling several bipolar divisions with a unified processing. Our idea is to design new variants of the classical Hash-Division algorithm, for dealing with the bipolar division. The issue of answers ranking is also dealt with. Computational experiments are carried out and demonstrate that the new variants outperform the conventional ones with respect to performance.

Applying Suitability Distributions in a Geological Context

Robin De Mol and Guy De Tré

Some industrial purposes require specific marine resources. Companies rely on information from resource models to decide where to go and what the cost will be to perform the required extractions. Such models, however, are typical examples of imprecise data sets wherein most data is estimated rather than measured. This is especially true for marine resource models, for which acquiring real data samples is a long and costly endeavor. Consequently, such models are largely computed by interpolating data from a small set of measurements. In this paper, we discuss how we have applied fuzzy set theory on a real data set to deal with these issues. It is further explained how the resulting fuzzy model can be queried so it may be used in a decision making context. To evaluate queries, we use a novel preference modeling and evaluation technique specifically suited for dealing with uncertain data, based on *suitability distributions*. The technique is illustrated by evaluating an example query and discussing the results.

Identifying Criteria Most Influencing Strategy Performance: Application to Humanitarian Logistical Strategy Planning

Cécile L'Héritier, Abdelhak Imoussaten, Sébastien Harispe, Gilles Dusserre and Benoît Roig

A growing interest is expressed by organizations for the development of approaches enabling to take advantage of past experiences to improve their decision processes; they may be referred to as Lessons Learned (LL) processes. Within the LL processes implementation framework, the development of semi-automatic approaches able to distinguish criteria having major influence on the evaluation of experiences is crucial for identifying relevant recommendations and performing efficient prescriptive analysis. In this paper, we propose to contribute to LL study by focusing on the definition of an approach enabling, in a specific setting, to identify the criteria most influencing the decision process regarding the overall performance evaluation of a reduced set of experiences.

The proposed approach is framed on Multi-Criteria Decision Analysis, and specifically is based on the Electre tri method.

In this paper, an illustration of the proposed approach is provided studying the evaluation of logistical response strategies in humanitarian emergency situations.

The use of fuzzy linguistic information and Fuzzy Delphi method to validate by consensus a questionnaire in a Blended-Learning environment

Jeovani Morales, Rosana Montes, Noe Zermeño, Jerónimo Durán and Francisco Herrera

The virtual learning landscapes have created complex environments when evaluating an educational experience. The Fuzzy Delphi method, which incorporates the theory of fuzzy sets, takes the opinions issued by judges, from a linguistic perspective, to validate a questionnaire that will measure the degree of success of an educational experience. The judges have to reach a consensus on the validity and applicability of the instrument. This work contributes to the validation of questionnaires by enabling linguistic assessments and not only binary answers and with a calculus of consistency and consensus degrees for each item, which contributes to consensus reaching. It has been use as a practical experience to define, with the consensus of nine experts, a questionnaire that measures the virtual communication and the satisfaction with in a Blended-Learning pilot experience in the subject of Software Fundamentals, 1st semester of the Degree in Computer Engineering of the University of Granada.

On the Interaction between Feature Selection and Parameter Determination in Fuzzy Modelling

Peipei Chen, Caro Fuchs, Anna Wilbik, Tak-Ming Chan, Saskia van Loon, Arjen-Kars Boer, Xudong Lu, Volkher Scharnhorst and Uzay Kaymak

Nowadays the amount of data that is collected in various settings is growing rapidly. These elaborate data records enable the training of machine learning models that can be used to extract insights and for making better informed decisions. When doing the data mining task, on one hand, feature selection is often used to reduce the dimensionality of the data. On the other hand, we need to decide the structure (parameters) of the model when building the model. However, feature selection and the parameters of the model may interact and affect the performance of the model. Therefore, it is difficult to decide the optimal parameter and the optimal feature subset without an exhaustive search of all the combination of the parameters and the feature subsets which is time-consuming. In this paper, we study how the interaction between feature selection and the parameters of a model affect the performance of the model through experiments on four data sets.

FS4RVDD: A Feature Selection Algorithm for Random Variables with Discrete Distribution

Fiorella Cravero, Santiago Schustik, María Jimena Martínez, Mónica Fátima Díaz and Ignacio Ponzoni

Feature Selection is a crucial step for inferring regression and classification models in QSPR (Quantitative Structure–Property Relationship) applied to Cheminformatics. A particularly complex case of QSPR modelling occurs in Polymer Informatics because the features under analysis require the management of uncertainty. In this paper, a novel feature selection method for addressing this special QSPR scenario is presented. The proposed methodology assumes that each feature is characterized by a probabilistic distribution of values associated with the polydispersity of the polymers included in the training dataset. This new algorithm has two sequential steps: ranking of the features, generated by correlation analysis, and iterative subset reduction, obtained by feature redundancy analysis. A prototype of the algorithm has been implemented in order to conduct a proof of concept. The method performance has been evaluated by using synthetic datasets of different sizes and varying the cardinality of the feature selected sub-sets. These preliminary results allow concluding that the chosen mathematical representation and the proposed method is suitable for managing the uncertainty inherent to the polymerization. Nevertheless, this research constitutes a piece of work in progress and additional experiments should be conducted in the future in order to assess the actual benefits and limitations of this methodology.

Clustering of Propositions Equipped with Uncertainty

Marek Z. Reformat, Jesse Xi Chen and Ronald R. Yager

Graph-based data representation formats enable more advanced processing of data that leads to better utilization of information stored and available on the web. Intrinsic high connectedness of such representation provides a means to create methods and techniques that can assimilate new data and build knowledge-like data structures. Such procedures resemble a human-like way of dealing with information.

In the paper, we focus on processing a knowledge graph data. In particular, we propose a simple way of clustering pieces of data that contain levels of uncertainty associated with them. That uncertainty is a result of collecting data from multiple sources. It is due to the fact that information about the same entities occurs a number of times and can be inconsistent. Existence of a number of 'alternative' pieces of data means that we can associate with them different levels of uncertainty. In order to accomplish that, we represent pieces of data from knowledge graphs as propositions with multiple alternatives. Each

alternative is associated with an uncertainty value expressing its 'correctness', i.e., a level of confidence that a given alternative represents an accurate piece of information. Those values are generated based on frequency of occurrence and consistency of alternatives. Our method is designed to cluster such propositions. The methodology is presented together with a number of illustrating examples.

Co-words Analysis of the Last Ten Years of the International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems

Manuel J. Cobo, Wanru Wang, Sigifredo Laengle, José M. Merigó, Dejian Yu and Enrique Herrera-Viedma

The main aim of this contribution is to develop a co-words analysis of the *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems* in the last ten years (2008–2017). The software tool SciMAT is employed using an approach that allows us to uncover the main research themes and analyze them according to their performance measures (qualitative and quantitative). An amount of 562 documents were retrieved from the Web of Science. The corpus was divided into two consecutive periods (2008–2012 and 2013–2017). Our key findings are that the most important research themes in the first and second period were devoted with decision making process and its related aspects, techniques and methods.

Robust Lookup Table Controller Based on Piecewise Multi-Linear Model for Nonlinear Systems with Parametric Uncertainty

Tadanari Taniguchi and Michio Sugeno

This paper proposes a robust lookup table controller based on piecewise multi-linear model for nonlinear systems with parametric uncertainty. We construct a piecewise multi-linear model of a nonlinear system. The model is a nonlinear approximation and the model can be derived from fuzzy if-then rules with singleton consequents. The piecewise model can be expressed as a lookup table. The model dynamics is described by multi-linear interpolation of the lookup table elements. We design a robust piecewise multi-linear controller for the piecewise model via feedback linearization. The robust piecewise controller can be also expressed as a lookup table. We apply the robust lookup table controller to ball and beam system as a nonlinear system with parametric uncertainty. Examples are shown to confirm the feasibility of our proposals by computer simulations.

A New Approach to Hellwig's Method of Data Reduction for Atanassov's Intuitionistic Fuzzy Sets

Eulalia Szmidt and Janusz Kacprzyk

We propose a new approach to Hellwig's method for the reduction of dimensionality of a data set using Atanassov's intuitionistic fuzzy sets (A-IFSs). We are mainly concerned with the dimension reduction for sets of data represented as the A-IFSs, and provide an illustrative example results which are compared with the results obtained by using the PCA (Principal Component Analysis) method. Remarks on comparisons with some other methods are also mentioned.

Towards a Semantic Gas Source Localization under Uncertainty

Javier Monroy, José-Raúl Ruiz-Sarmiento, Francisco-Ángel Moreno, Cipriano Galindo and Javier González-Jiménez

This work addresses the problem of efficiently and coherently locating a gas source in a domestic environment with a mobile robot, meaning *efficiently* the coverage of the shortest distance as possible and *coherently* the consideration of different gas sources explaining the gas presence. The main contribution is the exploitation, for the first time, of semantic relationships between the gases detected and the objects present in the environment to face this challenging issue. Our proposal also takes into account both the uncertainty inherent in the gas classification and object recognition processes. These uncertainties are combined through a probabilistic Bayesian framework to provide a priority-ordered list of (previously observed) objects to check. Moreover the proximity of the different candidates to the current robot location is also considered by a cost function, which output is used for planning the robot inspection path. We have conducted an initial demonstration of the suitability of our gas source localization approach by simulating this task within domestic environments for a variable number of objects, and comparing it with an greedy approach.

A Novel Uncertainty Quantification Method

Bas van Stein, Hao Wang, Wojtek Kowalczyk and Thomas Bäck

For most regression models, their overall accuracy can be estimated with help of various error measures. However, in some applications it is important to provide not only point predictions, but also to estimate the "uncertainty" of the prediction, e.g., in terms of confidence intervals, variances, or interquartile ranges. There are very few statistical modeling techniques able to achieve this.

For instance, the Kriging/Gaussian Process method is equipped with a theoretical mean squared error. In this paper we address this problem by introducing a heuristic method to estimate the uncertainty of the prediction, based on the error information from the k-nearest neighbours. This heuristic, called the *k-NN uncertainty measure*, is computationally much cheaper than other approaches (e.g., bootstrapping) and can be applied regardless of the underlying regression model. To validate and demonstrate the usefulness of the proposed heuristic, it is combined with various models and plugged into the well-known Efficient Global Optimization algorithm (EGO). Results demonstrate that using different models with the proposed heuristic can improve the convergence of EGO significantly.

Topological MI-groups: Initial Study

Michal Holčapek and Nicole Škorupová

In this paper, we introduce the concept of topological MI-groups, where the MI-group structure, which naturally generalizes the group structure, is enriched by a topology and the respective binary operation and inversion are continuous. To demonstrate that the proposed generalization of topological groups is meaningful, we prove that there are the products of topological MI-groups and the topological quotient MI-groups. The concept of topological MI-group is demonstrated on examples.

On Cantor's Theorem for Fuzzy Power Sets

Michal Holčapek

The aim of the paper is to introduce the concept of fuzzy power set in a universe of sets and investigate its basic properties. We focus here on an analysis of Cantor's theorem for fuzzy sets, which states in the set theory that the cardinality of a set is strictly smaller then the cardinality of its power set. For our investigation of Cantor's theorem we chose two types of equipollency of fuzzy sets, particularly, the binary Cantor's equipollence and its graded version.

The Relationship Between Graphical Representations of Regular Vine Copulas and Polytrees

Diana Carrera, Roberto Santana and José A. Lozano

Graphical models (GMs) are powerful statistical tools for modeling the (in)dependencies among random variables. In this paper, we focus on two different types of graphical models: R-vines and polytrees. Regarding the graphical representation of

these models, the former uses a sequence of undirected trees with edges representing pairwise dependencies, whereas the latter uses a directed graph without cycles to encode independence relationships among the variables. The research problem we deal with is whether it is possible to build an R-vine that represents the largest number of independencies found in a polytree and vice versa. Two algorithms are proposed to solve this problem. One algorithm is used to induce an R-vine that represents in each tree the largest number of graphical independencies existing in a polytree. The other one builds a polytree that represents all the independencies found in the R-vine. Through simple examples, both procedures are illustrated.

Implementing data envelopment analysis in an uncertain perception-based online evaluation environment

Debora Di Caprio and Francisco J. Santos-Arteaga

Consider a decision maker (DM) who must select an alternative to evaluate when using an online recommender engine that displays multiple evaluations from unknown raters regarding the different characteristics of the available alternatives. The evaluations of the raters do not necessarily coincide with those that would be provided by the DM, who must consider the differences existing between the ratings observed and his subjective perception and subsequent potential evaluations. We formalize the incentives of the DM to observe and evaluate an alternative through a function that accounts for these differences in a multi-criteria decision making setting. The resulting perception-based framework is implemented in a data envelopment analysis (DEA) scenario to analyze the effects of perception differentials on the evaluation and ranking behavior of DMs.

Constraint Shortest Path Problem in a Network with Intuitionistic Fuzzy Arc Weights

Homayun Motameni and Ali Ebrahimnejad

The Shortest Path (SP) problem is one of the most widely used problems in network optimization which has a wide range of applications in various fields of science and engineering such as communication, transportation, routing and scheduling. The aim of this problem is to find a minimum cost path between two specified nodes. In the present communication, we consider a modified version of the SP known as constraint SP (CSP) problem with an additional constraint that establishes an upper limit on the travel time for the path. The objective of the CSP problem is to determine a minimum cost path between two specified nodes that the traversal time of the path does not exceed from a

specified time. Traditional CSP problems assume the arc weights represented by time and cost are specified precisely. However, these weights can fluctuate with traffic conditions, weather, or payload. For this reason, being able to deal with vague and imprecise data may greatly contribute to the application of CSP problems. Here, we first formulate a CSP problem in a directed network where the arc weights represented by cost and time are intuitionistic trapezoidal fuzzy numbers. We then develop an approach for solving the intuitionistic fuzzy CSP problem under consideration. Finally, we present a small numerical example to illustrate the proposed approach.

A comparison between NARX Neural Networks and Symbolic Regression: An application for energy consumption forecasting

Ramón Rueda Delgado, Luis G. Baca Ruíz, Manuel Pegalajar Cuéllar, Miguel Delgado Calvo-Flores and María del Carmen Pegalajar Jiménez

Energy efficiency in public buildings has become a major research field, due to the impacts of the energy consumption in terms of pollution and economic aspects. For this reason, governments know that it is necessary to adopt measures in order to minimize the environmental impact and saving energy. Technology advances of the last few years allow us to monitor and control the energy consumption in buildings, and become of great importance to extract hidden knowledge from raw data and give support to the experts in decision-making processes to achieve real energy saving or pollution reduction among others. Prediction techniques are classical tools in machine learning, used in the energy efficiency paradigm to reduce and optimize the energy using. In this work we have used two prediction techniques, symbolic regression and neural networks, with the aim of predict the energy consumption in public buildings at the University of Granada. This paper concludes that symbolic regression is a promising and more interpretable results, whereas neural networks lack of interpretability take more computational time to be trained. In our results, we conclude that there are no significant differences in accuracy considering both techniques in the problems addressed.

A Bibliometric Analysis of the Explainable Artificial Intelligence Research Field

Jose M. Alonso, Ciro Castiello and Corrado Mencar

This paper presents the results of a bibliometric study of the recent research on eXplainable Artificial Intelligence (XAI) systems. We took a global look at the contributions of scholars in XAI as well as in the subfields of AI that are mostly involved in the development of XAI systems. It is worthy to remark that we

found out that about one third of contributions in XAI come from the fuzzy logic community. Accordingly, we went in depth with the actual connections of fuzzy logic contributions with AI to promote and improve XAI systems in the broad sense. Finally, we outlined new research directions aimed at strengthening the integration of different fields of AI, including fuzzy logic, toward the common objective of making AI accessible to people.

Do Hierarchical Fuzzy Systems really improve interpretability?

Luis Magdalena

Fuzzy systems have demonstrated a strong modeling capability. The quality of a fuzzy model is usually measured in terms of its accuracy and interpretability. While the way to measure accuracy is in most cases clear, measuring interpretability is still an open question.

The use of hierarchical structures in fuzzy modeling as a way to reduce complexity in systems with many input variables has also shown good results. This complexity reduction is usually considered as a way to improve interpretability, but the real effect of the hierarchy on interpretability has not really been analyzed.

The present paper analyzes that complexity reduction comparing it with that of other techniques such as feature extraction, to conclude that only the use of intermediate variables with meaning (from the point of view of model interpretation) will ensure a real interpretability improvement due to the hierarchical structure.

Human Players versus Computer Games Bots: A Turing test based on Linguistic Description of Complex Phenomena and Restricted Equivalence Functions

Clemente Rubio-Manzano, Tomás Lermanda-Senoceaín, Christian Vidal-Castro, Alejandra Segura-Navarrete and Claudia Martínez-Araneda

This paper aims to propose a new version of the well-known Turing Test for computer game bots based on Linguistic Description of Complex Phenomena and Restricted Equivalence Functions whose goal is to evaluate the "believability" of the computer games bots acting in a virtual world. A data-driven software architecture based on Linguistic Modelling of Complex Phenomena is also proposed which allows us to automatically generate bots behavior profiles. These profiles can be compared with human players behavior profiles in order to provide us with a similarity measure of "believability" between them. In order

to show and explore the possibilities of this new turing test, a web platform has been designed and implemented by one of authors.

Reinterpreting Interpretability for Fuzzy Linguistic Descriptions of Data

Alejandro Ramos-Soto and Martín Pereira-Fariña

We approach the problem of interpretability for fuzzy linguistic descriptions of data from a natural language generation perspective. For this, first we review the current state of linguistic descriptions of data and their use contexts as a standalone tool and as part of a natural language generation system. Then, we discuss the standard approach to interpretability for linguistic descriptions and introduce our complementary proposal, which describes the elements from linguistic descriptions of data that can influence and improve the interpretability of automatically generated texts (such as fuzzy properties, quantifiers, and truth degrees), when linguistic descriptions are used to determine relevant content within a text generation system.

Tell Me Why: Computational Explanation of Conceptual Similarity Judgments

Davide Colla, Enrico Mensa, Daniele P. Radicioni and Antonio Lieto

In this paper we introduce a system for the computation of explanations that accompany scores in the conceptual similarity task. In this setting the problem is, given a pair of concepts, to provide a score that expresses in how far the two concepts are similar. In order to explain how explanations are automatically built, we illustrate some basic features of COVER, the lexical resource that underlies our approach, and the main traits of the MeRaLi system, that computes conceptual similarity and explanations, all in one. To assess the computed explanations, we have designed a human experimentation, that provided interesting and encouraging results, which we report and discuss in depth.

Multi-operator Decision Trees for Explainable Time-Series Classification

Vera Shalaeva, Sami Alkhoury, Julien Marinescu, Cécile Amblard and Gilles Bisson

Analyzing time-series is a task of rising interest in machine learning. At the same time developing interpretable machine learning tools is the recent challenge proposed by the industry to ease use of these tools by engineers and domain experts. In the paper we address the problem of generating interpretable classification

of time-series data. We propose to extend the classical decision tree machine learning algorithm to Multi-operator Temporal Decision Trees (MTDT). The resulting algorithm provides interpretable decisions, thus improving the results readability, while preserving the classification accuracy. Aside MTDT we provide an interactive visualization tool allowing a user to analyse the data, their intrinsic regularities and the learned tree model.

Comparison-based Inverse Classification for Interpretability in Machine Learning

Thibault Laugel, Marie-Jeanne Lesot, Christophe Marsala, Xavier Renard and Marcin Detyniecki

In the context of post-hoc interpretability, this paper addresses the task of explaining the prediction of a classifier, considering the case where no information is available, neither on the classifier itself, nor on the processed data (neither the training nor the test data). It proposes an inverse classification approach whose principle consists in determining the minimal changes needed to alter a prediction: in an instance-based framework, given a data point whose classification must be explained, the proposed method consists in identifying a close neighbor classified differently, where the closeness definition integrates a sparsity constraint. This principle is implemented using observation generation in the *Growing Spheres* algorithm. Experimental results on two datasets illustrate the relevance of the proposed approach that can be used to gain knowledge about the classifier.

Mapping Utilities to Transitive Preferences

Thomas A. Runkler

This article deals with the construction of (pairwise) preference relations from degrees of utilities, e.g. ratings. Recently, the U2P method has been proposed for this purpose, but U2P is neither additively nor multiplicatively transitive. This paper proposes the U2PA and the U2PM methods. U2PA is additively transitive, and U2PM is multiplicatively transitive. Moreover, both U2PA and U2PM have linear preference over ambiguity.

On the structure of group-like $\mathbf{FL}_e$-chains

Sándor Jenei

Hahn's celebrated embedding theorem asserts that linearly ordered Abelian groups embed in the *lexicographic product* of real groups [**?**]. In this paper the *partial*-lexicographic product construction is introduced, a class of residuated

monoids, namely, group-like FL_e-chains which possess finitely many idempotents are *embedded* into finite partial-lexicographic products of linearly ordered Abelian groups, that is, Hahn's theorem is extended to this residuated monoid class. As a side-result, the strong standard completeness of logic $\mathbf{IUL}^{fp}$ is announced.

First steps towards harnessing partial functions in fuzzy type theory

Vilém Novák

In this paper we present how the theory of partial functions can be developed in the fuzzy type theory and show how the theory elaborated by Lapierre [**?**] and Lepage [**?**] can be included in it. Namely, the latter is developed as a special theory whose models contain the partial functions in the sense introduced by both authors.

Logics for strict coherence and Carnap-regular probability functions

Tommaso Flaminio

In this paper we provide a characterization of strict coherence in terms of the logical consistency of suitably defined formulas in fuzzy-modal logics for probabilistic reasoning. As a direct consequence of our characterization, we also show the decidability for the problem of checking the strict coherence of rational-valued books on classical events. Further, we introduce a fuzzy modal logic that captures Carnap-regular probability functions, that is normalized and finitely additive measures which maps to 0 only the impossible event.

Connecting systems of mathematical fuzzy logic with fuzzy concept lattices

Pietro Codara, Francesc Esteva, Lluís Godo and Diego Valota

In this paper our aim is to explore a new look at formal systems of fuzzy logics using the framework of (fuzzy) formal concept analysis (FCA). Let L be an extension of MTL complete with respect to a given L-chain. We investigate two possible approaches. The first one is to consider fuzzy formal contexts arising from L where attributes are identified with L-formulas and objects with L-evaluations: every L-evaluation (object) satisfies a formula (attribute) to a given degree, and vice-versa. The corresponding fuzzy concept lattices are shown to be isomorphic to quotients of the Lindenbaum algebra of L. The second one, following an idea in a previous paper by two of the authors for the particular case

of Gödel fuzzy logic, is to use a result by Ganter and Wille in order to interpret the (lattice reduct of the) Lindenbaum algebra of L-formulas as a (classical) concept lattice of a given context.

Characterizing fuzzy y-models in multi-adjoint normal logic programming

M. Eugenia Cornejo, David Lobo and Jesús Medina

This paper includes the main notions associated with the syntax and semantics of two interesting paradigms in fuzzy logic programming with default negation: multi-adjoint normal logic programming introduced in [5] and the fuzzy answer set logic programming approach presented in [16]. We will show that fuzzy answer set logic programs can be translated into multi-adjoint normal logic programs, as long as the implication operator used in the former is a residuated implication. Moreover, we will relate the notions of fuzzy y-model and model by means of a characterization theorem which allow us to guarantee the existence of fuzzy y-models of fuzzy answer set logic programs.

Natural extension of choice functions

Arthur Van Camp, Enrique Miranda and Gert de Cooman

We extend the notion of natural extension, that gives the least committal extension of a given assessment, from the theory of sets of desirable gambles to that of choice functions. We give an expression of this natural extension and characterise its existence by means of a property called avoiding complete rejection. We prove that our notion reduces indeed to the standard one in the case of choice functions determined by binary comparisons, and that these are not general enough to determine all coherent choice function. Finally, we investigate the compatibility of the notion of natural extension with the structural assessment of indifference between a set of options.

Approximations of coherent lower probabilities by 2-monotone capacities

Ignacio Montes, Enrique Miranda and Paolo Vicig

We investigate the problem of approximating a coherent lower probability on a finite space by a 2-monotone capacity that is at the same time as close as possible while not including additional informa- tion. We show that this can be tackled by means of a linear programming problem, and investigate the features of the set of undominated solutions. While our approach is based on a distance proposed by Baroni and Vicig, we also discuss a number of alternatives. Finally,

we show that our work applies to the more general problem of approximating coherent lower previsions.

Web Apps & Imprecise Probabilitites

Jorge Castro, Joaquim Gabarro and Maria Serna

We propose a model for the behaviour of Web apps in the unreliable WWW. Web apps are described by orchestrations. An orchestration mimics the personal use of the Web by defining the way in which Web services are invoked. The WWW is unreliable as poorly maintained Web sites are prone to fail. We model this source of unreliability trough a probabilistic approach. We assume that each site has a probability to fail. Another source of uncertainty is the traffic congestion. This can be observed as a non-deterministic behaviour induced by the variability in the response times. We model non-determinism by imprecise probabilities. We develop here an ex-ante normal to characterize the behaviour of finite orchestrations in the unreliable Web. We show the existence of a normal form under such semantics for orchestrations using asymmetric parallelism.

Conditional submodular coherent risk measures

Giulianella Coletti, Davide Petturiti and Barbara Vantaggi

A family of conditional risk measures is introduced by considering a single period financial market, relying on a notion of conditioning for submodular capacities, which generalizes that introduced by Dempster. The resulting measures are expressed as discounted conditional Choquet expected values, take into account ambiguity towards uncertainty and allow for conditioning to "null" events. We also provide a characterisation of consistence of a partial assessment with a conditional submodular coherent risk measure. The latter amounts to test the solvability of a suitable sequence of linear systems.

Virtual Subconcept Drift Detection in Discrete Data Using Probabilistic Graphical Models

Rafael Cabañas, Andrés Cano, Manuel Gómez-Olmedo, Andrés R. Masegosa and Serafín Moral

A common problem in mining data streams is that the distribution of the data might change over time. This situation, which is known as concept drift, should be detected for ensuring the accuracy of the models. In this paper we propose a method for subconcept drift detection in discrete streaming data using probabilistic graphical models. In particular, our approach is based on the use of conditional linear Gaussian Bayesian networks with latent variables. We demonstrate and analyse the proposed model using synthetic and real data.

MOLP Approach for Solving Transportation Problems with Intuitionistic Fuzzy Costs

Ali Ebrahimnejad and José Luis Verdegay

Many researchers have focused on a Transportation Problem (TP) in uncertain environment because of its importance to various applications. This paper is concerned with the solution procedure of a TP in which transportation costs are represented in terms of intuitionistic triangular fuzzy numbers and supplies and demands are real numbers. We first formulate the intuitionistic fuzzy TP (IFTP) and then propose a new solution technique to solve the problem. Based on the proposed approach, the IFTP is converted into a Multi Objective Linear Programming (MOLP) problem with five objective functions. Then, a lexicographic approach is used to obtain the efficient solution of the resulting MOLP problem. The optimization process confirms that the optimum intuitionistic fuzzy transportation cost preserves the form of an intuitionistic triangular fuzzy number. A simple numerical example is included to illustrate of the proposed technique. The obtained results confirm the reliability and applicability of the proposed approach.

Context-based Decision and Optimization: the Case of the Maximal Coverage Location Problem

María T. Lamata, David A. Pelta , Alejandro Rosete and José L. Verdegay

Every decision problem, understood as the need to take the best decision in some sense, leads to an optimization problem. There is a need to consider the "context" where each decision is made because it directly affects the underlying decision/optimization model with obvious implications in the change of the optimal solutions.

In this contribution this topic is further explored using the problem of locating emergency services (ambulances) in a set of available locations. A number of different contexts are considered and how they can be defined from an operational point of view is shown. The results obtained allowed to show how the best solutions of the problem may change.

Even using this simple example, we can conclude that the role of the context in decision/optimization problems and the need to properly define it should not be underestimated.

Reliability Improvement of Odour Detection Thresholds Bibliographic Data

Pascale Montreer, Stefan Janaqi, Stéphane Cariou, Mathilde Chaignaud, Isabelle Betremieux, Philippe Ricoux, Frédéric Picard, Sabine Sirol, Budagwa Assumani and Jean-Louis Fanlo

Odour control is an important industrial issue as it is a criterion in purchase of a material. The minimal concentration of a pure compound allowing to perceive its odour, called Odour Detection Threshold (ODT), is a key of the odour control. Each compound has its own ODT. Literature is the main source to obtain ODT, but a lot of compounds are not reported and, when reported, marred by a high variability. This paper proposes a supervised cleaning methodology to reduce uncertainty of available ODTs and a prediction of missing ODTs on the base of physico-chemical variables.

This cleaning leads to eliminate 39% of reported compounds while conducting 84% of positive scenarios on 37 comparisons. Missing ODTs are predicted with an error of 0.83 for the train and 1.14 for the test (log10 scale). Given the uncertainty of data, the model is sufficient. This approach allows working with a lower uncertainty and satisfactory prediction of missing ODTs.

A Decision Support System based on a Hybrid Genetic Local Search heuristic for solving the Dynamic Vehicle Routing Problem: Tunisian Case

Ines Sbai, Olfa Limam and Saoussen Krichen

Vehicle Routing Problem is the most common and simplest routing problems. One of its important variants is the Dynamic Vehicle Routing Problem in which a new customer orders and order cancellations continually happen over time and thus perturb the optimal routing schedule that was originally invented. The Dynamic Vehicle Routing Problem is an *NP-H*ard problem aims to design the route set of minimum cost for a homogenous feet of vehicles, starting and terminating at the depot, to serve all the customers. In this paper, we propose a prototype of a Decision Support System that integrates a hybrid of Genetic Algorithm and Local Search to solve the Dynamic Vehicle Routing Problem . The performance of the proposed algorithm is highlighted through the implementation of the Decision Support System. Some benchmark problems are selected to test the performance of the proposed hybrid method. Our approach is better than the performance of compared algorithms in most cases in terms of solution quality and robustness. In order to demonstrate the performance of the proposed Decision Support System in term of solution quality, we apply it for a real case of the Regional Post Office of the city of Kef in the north west of

Tunisia. The results are then highlighted in a cartographic format using Google Maps.

Fuzzy Boundary Weak Implications

Hua-Wen Liu and Michał Baczyński

An extension of fuzzy implications and coimplications, called fuzzy boundary weak implications (shortly, fuzzy bw-implications), is introduced and discussed in this paper. Firstly, by weakening the boundary conditions of fuzzy implications and coimplications, we introduce the concept of fuzzy bw-implications. And then, we investigate some of their basic properties. Next, the concept of fuzzy pseudo-negations is introduced and the natural pseudo-negations of fuzzy bw-implications are investigated. Finally, the fuzzy bw-implications generated, respectively, by aggregation operators and generator functions are discussed in details. This work is motivated by the fact that in real applications there are used some operators which are not not fuzzy implications. We hope that such an extension of fuzzy (co)implications can provide a certain theoretical foundation for the real applications.

On linear and quadratic constructions of fuzzy implication functions

Sebastia Massanet, Juan Vicente Riera and Joan Torrens

In this paper a new construction method of fuzzy implication functions from a given one, based on ternary polynomial functions is presented. It is proved that the case of linear polynomial functions leads only to trivial solutions and thus the quadratic case is studied in depth. It is shown that the quadratic method allows many different possibilities depending on the usual properties of fuzzy implications functions that we want to preserve. Specifically, there are infinitely many quadratic functions that transform fuzzy implication functions satisfying properties like the neutrality principle, the identity principle, or the law of contraposition with respect to the classical negation, into new fuzzy implication functions satisfying them.

On the characterization of a family of generalized Yager's implications

Raquel Fernández-Peralta and Sebastia Massanet

Over the last years, several generalizations of Yager's f and g-generated implications have been proposed in the literature expanding the number of available families of fuzzy implication functions. Among them, the so-called (f, g) and

(g, f)-implications were introduced by means of generalizing the internal functions x and $\frac{1}{x}$ of the standard Yager's f and g-generated implications to more general unary functions. In particular, those generated using $\frac{x}{e}$ and $\frac{e}{x}$ with $e \in (0, 1)$ stand out due to their key role in the structure of (h, e)-implications. In this paper, the characterizations of the $(f, \frac{x}{e})$-implications are presented. These characterizations, which rely on two properties closely related to the law of importation, will be crucial in order to achieve a fully axiomatic characterization of (h, e)-implications.

Generalized Modus Ponens for (U, N)-implications

Margarita Mas, Daniel Ruiz-Aguilera and Joan Torrens

The Modus Ponens becomes an essential property in approximate reasoning and fuzzy control when forward inferences are managed. Thus, the conjunctor and the fuzzy implication function used in the inference process are required to satisfy this property. Usually, the conjunctor is modeled by a t-norm, but recently also by conjunctive uninorms. In this paper we study when (U, N)-implications satisfy the Modus Ponens property with respect to a conjunctive uninorm U in general, in a similar way as it was previously done for RU-implications. The functional inequality derived from the Modus Ponens involves in this case two different uninorms and a fuzzy negation leading to many possibilities. So, this communication presents only a first step in this study and many cases depending on the classes of the involved uninorms are worth to study.

Dependencies between some types of fuzzy equivalences

Urszula Bentkowska and Anna Król

The article deals with diverse types of fuzzy equivalences interpreted as fuzzy connectives. It presents some dependencies between well known fuzzy C-equivalences as well as lately examined fuzzy α–C-equivalences, fuzzy semi-C-equivalences, fuzzy weak C-equivalences, and a fuzzy equivalence defined by Fodor and Roubens.

Selected Properties of Generalized Hypothetical Syllogism Including the Case of R-implications

Michał Baczyński and Katarzyna Miś

In this paper we investigate the generalized hypothetical syllogism (GHS) in fuzzy logic, which can be seen as the functional equation $\sup_{z\in[0,1]} T(I(x, z)I(z, y)) = I(x, y)$, where I is a fuzzy implication and T is a t-norm. Our contribution is

inspired by the article [N.R. Vemuri, Investigations of fuzzy implications satisfying generalized hypothetical syllogism, Fuzzy Sets and Systems 323 (2017) 117–137], where the author considered (GHS) when T is the minimum t-norm. We show several general results and then we focus on R-implications. We characterize all t-norms which satisfy (GHS) with arbitrarily fixed R-implication generated from a left-continuous t-norm.

Soft computing techniques applied to munsell soil color charts modelling

María del Carmen Pegalajar, Manuel Sánchez-Marañón, Luis Gonzaga Baca-Ruiz, Luis Mansilla and Miguel Delgado Calvo-Flores

The Munsell soil-color charts contain 238 standard color chips arranged in seven charts with Munsell notation. They are widely used to determine soil color by visual comparison, seeking the closest match between a soil sample and one of the chips. The Munsell designation of this chip (hue, value, and chroma) is assigned to the soil under study. However, the available chips represent only a subset of all possible soil colors, in which the visual appearance for an observer is usually intermediate between several chips. Our study proposes an intelligent system which combines two Soft Computing Techniques (Artificial Neural Networks and Fuzzy Logic Systems) aimed at finding a set of chips as similar as possible to a given soil sample. This is under the precondition that the soil sample is an image taken by a digital camera or mobile phone. The system receives an image as input and returns a set of color-chip designations as output.

Steinhaus transforms of fuzzy string distances in computational linguistics

Anca Dinu, Liviu P. Dinu, Laura Franzoi and Andrea Sgarro

In this paper we deal with distances for fuzzy strings in $[0,1]^n$, to be used in distance-based linguistic classification. We start from the fuzzy Hamming distance, anticipated by the linguist Ž. Muljačić back in 1967, and the taxicab distance, which both generalize the usual crisp Hamming distance, using in the first case the standard logical operations of minimum for conjunctions and maximum for disjunctions, while in the second case one uses Łukasiewicz' T-norms and T-conorms. We resort to the Steinhaus transform, a powerful tool which allows one to deal with linguistic data which are not only fuzzy, but possibly also irrelevant or logically inconsistent. Experimental results on actual data are shown and preliminarily commented upon.

Size-based super level measures on discrete space

Jana Borzová, Lenka Halčinová and Jaroslav Šupina

We continue in the investigation of a concept of size introduced by Y. Do and C. Thiele [3]. Our focus is a computation of corresponding super level measure, a key component of size application, on discrete space, i.e., a finite set with discrete topology. We found critical numbers which determine the change of a value of super level measure and we present an algorithm for super level measure computation based on these numbers.

Modified Methods of Capital Budgeting under Uncertainties: An Approach Based on Fuzzy Numbers and Interval Arithmetic

Antonio C. de S. Sampaio Filho, Marley M. B. R.Vellasco and Ricardo Tanscheit

The fuzzy modified net present value (Fuzzy MNPV) method for evaluation of non-conventional investment projects under uncertainty explicitly provided for the use of the opportunity costs associated with the interim cash flows of an investment project and eliminated the major problems of traditional capital budgeting methods. Based on the same assumptions that guided the development of that method, the current paper presents a unified capital budgeting solution, consisting of the modified internal rate of return (Fuzzy MIRR), the modified profitability index (Fuzzy MPI), and the modified total payback (Fuzzy MTPB). These methods are MNPV-consistent, maximize shareholder wealth and always lead to the same conditions of acceptance or rejection of investment projects.

Solving job-shop scheduling problems with fuzzy processing times and fuzzy due dates

Camilo Alejandro Bustos-Tellez, Jhoan Sebastian Tenjo-García and Juan Carlos Figueroa-García

This paper shows an iterative method for solving n-jobs, m-machines scheduling problems with fuzzy processing times and fuzzy due dates which are defined using third-party information coming from experts. We use an iterative method based on the cumulative membership function of a fuzzy set to find an overall satisfaction degree among fuzzy processing times and fuzzy due dates.

Measuring features strength in probabilistic classification

Rosario Delgado and Xavier-Andoni Tibau

Probabilistic classifiers output a probability of an input being a member of each of the possible classes, given some of its feature values, selecting most probable class as predicted class. We introduce and compare different measures of the feature strength in probabilistic confidence-weigthed classification models. For that, we follow two approaches: one based on conditional probability tables of the classification variable with respect to each feature, using different statistical distances and a correction parameter, and the second one based on accuracy in predicting classification from evidences on each isolated feature. On a case study, we compute these feature strength measures and rank features attending to them, comparing results.

DETD: Dynamic policy for case base maintenance based on EK-NNclus algorithm and case Types Detection

Safa Ben Ayed, Zied Elouedi and Eric Lefèvre

Case Based Reasoning (CBR) systems know a success in various domains. Consequently, we find several works focusing on Case Base Maintenance (CBM) that aim to preserve CBR systems performance. Thus, CBM tools are generally offering techniques to select only the most potential cases for problem-solving. However, cases are full of imperfection since they represent real world situations, which makes this task harder. In addition, new problems having substantially new solutions will be found in case bases over the time. Hence, we aim, in this paper, to propose a new CBM approach having the ability to manage uncertainty and the dynamic aspect of maintenance using the evidential clustering technique called EK-NNclus based on belief function theory, where clusters' number is fixed automatically and changes from one maintenance application to another. Finally, the maintenance task is performed through selecting only two types of cases.

Ensemble Enhanced Evidential k-NN classifier through rough set reducts

Asma Trabelsi, Zied Elouedi and Eric Lefèvre

Data uncertainty is seen as one of the main issues of several real world applications that can affect the decision of experts. Several studies have been carried out, within the data mining and the pattern recognition fields, for processing

the uncertainty that is associated to the classifier outputs. One solution consists of transforming classifier outputs into evidences within the framework of belief functions. To gain the best performance, ensemble systems with belief functions have been well studied for several years now. In this paper, we aim to construct an ensemble of the Evidential Editing k-Nearest Neighbors classifier (EEk-NN), which is an extension of the standard k-NN classifier for handling data with uncertain attribute values expressed within the belief function framework, through rough set reducts.

Towards a Hybrid User and Item-based Collaborative Filtering under the Belief Function Theory

Raoua Abdelkhalek, Imen Boukhris and Zied Elouedi

Collaborative Filtering (CF) approaches enjoy considerable popularity in the field of Recommender Systems (RSs). They exploit the users' past ratings and provide personalized recommendations on this basis. Commonly, neighborhood-based CF approaches focus on relationships between items (item-based) or, alternatively, between users (user-based). User-based CF predicts new preferences based on the users sharing similar interests. Item-based computes the similarity between items rather than users to perform the final predictions. However, in both approaches, only partial information from the rating matrix is exploited since they rely either on the ratings of similar users or similar items. Besides, the reliability of the information provided by these pieces of evidence as well as the final predictions cannot be fully trusted. To tackle these issues, we propose a new hybrid neighborhood-based CF under the belief function framework. Our approach tends to take advantage of the two kinds of information sources while handling uncertainty pervaded in the predictions. Pieces of evidence from both items and users are combined using Dempster's rule of combination. The performance of the new recommendation approach is validated on a real-world data set and compared to state of the art CF neighborhood approaches under the belief function theory.

Evidential Top-k Queries Evaluation: Algorithms and Experiments

Fatma Ezzahra Bousnina , Mouna Chebbah, Mohamed Anis Bach Tobji, Allel HadjAli and Boutheina Ben Yaghlane

Top-k queries represent a vigorous tool to rank-order answers and return only the most interesting ones. ETop-k queries were introduced to discriminate answers in the context of evidential databases. Due to their interval degrees, such answers seem to be difficult to rank-order and to interpret. Two methods of

ranking intervals were proposed in the evidential context. This paper presents an efficient implementation of these methods and discusses the experimental results obtained.

Independence of Sources in Social Networks

Manel Chehibi, Mouna Chebbah and Arnaud Martin

Online social networks are more and more studied. The links between users of a social network are important and have to be well qualified in order to detect communities and find influencers for example. In this paper, we present an approach based on the theory of belief functions to estimate the degrees of cognitive independence between users in a social network. We experiment the proposed method on a large amount of data gathered from the Twitter social network.

Foreground detection enhancement using Pearson correlation filtering

Rafael Marcos Luque-Baena, Miguel A. Molina-Cabello, Ezequiel López-Rubio and Enrique Domínguez

Foreground detection algorithms are commonly employed as an initial module in video processing pipelines for automated surveillance. The resulting masks produced by these algorithms are usually postprocessed in order to improve their quality. In this work, a postprocessing filter based on the Pearson correlation among the pixels in a neighborhood of the pixel at hand is proposed. The flow of information among pixels is controlled by the correlation that exists among them. This way, the filtering performance is enhanced with respect to some state of the art proposals, as demonstrated with a selection of benchmark videos.

Identifying pixels classified uncertainties ckMeansImage algorithm

Rogério R. de Vargas, Ricardo Freddo, Cristiano Galafassi, Sidnei L. B. Gass, Alexandre Russini and Benjamín Bedregal

Floods may occur in rivers when the flow rate exceeds the capacity of the river channel, particularly at bends or meanders in the waterway. Floods often cause damage to homes and businesses becoming the most prevalent type of disaster in the world and the one with the highest number of events, causing the greatest economic losses, affecting a large number of people. This paper has the objective of mapping and identifying the flooding areas of a selected region in the municipality of Itaqui-RS using remote sensing. In order to do it, we

used the Fuzzy ckMeansImage Algorithm to group and to classify the image into similarity clusters. The methodology consists in processing satelite images before and after the flooding occurs. Finally, we discuss the processed images and present the flooded area.

Automatic Detection of Thistle-Weeds in Cereal Crops from Aerial RGB Images

Camilo Franco, Carely Guada, J. Tinguaro Rodríguez, Jon Nielsen, Jesper Rasmussen, Daniel Gómez and Javier Montero

Capturing aerial images by Unmanned Aerial Vehicles (UAV) allows gathering a general view of an agricultural site together with a detailed exploration of its relevant aspects for operational actions. Here we explore the challenging task of detecting *cirsium arvense*, a thistle-weed species, from aerial images of barley-cereal crops taken from 50m above the ground, with the purpose of applying herbicide for site-specific weed treatment. The methods for automatic detection are based on object-based annotations, pointing out the RGB attributes of the Weed or Cereal classes for an entire group of pixels, referring to a crop area which will have to be treated if it is classified as being of the Weed class. In this way, an annotation belongs to the Weed class if more than half of its area is known to be covered by thistle weeds. Hence, based on object and pixel-level analysis, we compare the use of k-Nearest Neighbours (k-NN) and (feed-forward, one-hidden layer) neural networks, obtaining the best results for weed detection based on pixel-level analysis, based on a soft measure given by the proportion of predicted weed pixels per object, with a global accuracy of over 98%.

Navigating the meaning and uncertainty hierarchy within image scenes and the words that describe them

Lauren Barghout

This paper explores the meaning and uncertainty inherent in (a) understanding image hierarchies; (b) describing them with words; and (c) navigating the abstraction context of the viewer. A spatial-taxon hierarchy, a standardized scene architecture, partitions an image into a foreground, subject and salient objects and/or sub-objects. The introduction starts with a thought experiment based on a poem & an image landscape. The thought experiment is intended to provide analogical inference as scaffolding for the rest of the paper. The results of experimental data of human annotated spatial-taxon and corresponding word descriptions of two images are presented. The experimental results are analyzed in terms of spatial-taxon designation and the meaning & uncertainty

presented by the human annotations. The results support the fuzzy spatial-taxon hierarchy of human scene perception described by other works, show that word descriptions depend on spatial-taxon designation and that long tail word distributions require unbounded possibility with semantic uncertainty (type 2 fuzzy sets) for the word counts in the probability distribution. Deep learning image recognition, Zadeh information restriction principal, Shannon' s distinction between information content and semantics, customized image descriptions and fuzzy inference techniques are explored.

T-overlap Functions: a generalization of bivariate overlap functions by t-norms

Hugo Zapata, Graçaliz P. Dimuro, Javier Fernández and Humberto Bustince

This paper introduces a generalization of overlap functions by extending one of the boundary conditions of its definition. More specifically, instead of requiring that "the considered function is equal to zero if and only if some of the inputs is equal to zero", we allow the range in which some t-norm is zero. We call such generalization by a t-overlap function with respect to such t-norm. Then we analyze the main properties of t-overlap function and introduce some construction methods.

On the Existence and Uniqueness of Fixed Points of Fuzzy Cognitive Maps

István Á. Harmati, Miklós F. Hatwágner and László T. Kóczy

Fuzzy Cognitive Maps (FCMs) are decision support tools, which were introduced to model complex behavioral systems. The final conclusion (output of the system) relies on the assumption that the system reaches an equilibrium point (fixed point) after a certain number of iteration. It is not straightforward that the iteration leads to a fixed point, since limit cycles and chaotic behaviour may also occur.

In this article, we give sufficient conditions for the existence and uniqueness of the fixed point for log-sigmoid and hyperbolic tangent FCMs, based on the weighted connections between the concepts and the parameter of the threshold function. Moreover, in a special case, when all of the weights are non-negative, we prove that fixed point always exists, regardless of the parameter of the threshold function.

Searching Method of Fuzzy Internally Stable Set as Fuzzy Temporal Graph Invariant

Alexander Bozhenyuk, Stanislav Belyakov, Margarita Knyazeva and Igor Rozenberg

In this paper we consider the problem of finding the invariant of a fuzzy temporal graph, namely, a fuzzy internally stable set. Fuzzy temporal graph is a generalization of a fuzzy graph on the one hand, and a temporal graph on the other hand. In this paper, a temporal fuzzy graph is considered, in which the connectivity degree of vertices varies in discrete time. The notion of maximum internally stable subset of fuzzy temporal graph is considered. A method and an algorithm for finding all maximal internally stable sets are proposed which makes it possible to find a fuzzy internally stable set. The example of definition of internal stable fuzzy set is considered as well.

Prioritisation of Nielsen's Usability Heuristics for User Interface Design Using Fuzzy Cognitive Maps

Rita N. Amro, Saransh Dhama, Muhanna Muhanna and László T. Kóczy

Usability Heuristics are being widely used as a means of evaluating user interfaces. However, little existing work has been done that focused on assessing the effect of these heuristics individually or collectively on said systems. In this paper, the authors propose an approach to evaluating the usability of systems that deploys a prioritised version of Nielsen's usability heuristics. Fuzzy cognitive maps were used to prioritise the original heuristics according to experts in both fields. Using either set of heuristics evaluators can identify the same number of usability issues. However, when trying to enhance the overall usability of a system, the prioritised set of heuristics can help stakeholders focus their limited resources on fixing the subset of issues that collectively has the worst effect on the usability of their systems during each iteration. To test the findings proposed by authors several websites were evaluated for various usability problems. The experimental results show that by using the proposed heuristics, evaluators were able to find a comparable number of problems to those who used Nielsen's, the prioritised heuristics resulted in an ordered list of issues based on their effect on usability. Therefore, the authors believe that heuristic evaluation in general, and their introduced heuristics in particular, are effective in dealing with issues when facing situations of limited resources.

Discrete Bacterial Memetic Evolutionary Algorithm for the Time Dependent Traveling Salesman Problem

Boldizsár Tüű-Szabó, Péter Földesi, and László T. Kóczy

The Time Dependent Traveling Salesman Problem (TDTSP) that is addressed in this paper is a variant of the well-known Traveling Salesman Problem. In this problem the distances between nodes vary in time (are longer in rush hours in the city centre), Our Discrete Bacterial Evolutionary Algorithm (DBMEA) was tested on benchmark problems (on bier127 and on a self-generated problem with 250 nodes) with various jam factors. The results demonstrate the effectiveness of the algorithm.

Fuzzy association rules on data with undefined values

Petra Murinová, Viktor Pavliska and Michal Burda

Handling of missing values is a very common in data processing. However, data values may be missing not only because of lack of information, but also because of undefinedness (such as asking for the age of non-married person's spouse). The aim of this paper is to propose an extension of fuzzy association rules framework for data with undefined values.

On the use of subproduct in fuzzy relational compositions based on grouping features

Nhung Cao, Martin Štěpnička, Michal Burda and Aleš Dolný

Fuzzy relational compositions have been extended and studied from distinct perspectives, and their use on the classification problem has been already demonstrated too. One of the recent approaches foreshadowed the positive influence of the so-called grouping features. When this improvement is being applied, the universe of features is partitioned into a number of groups of features and then the relevant composition is applied. The use of the concept was demonstrated on the real classification of Odonata (dragonflies). This paper shows that the Bandler-Kohout subproduct may appropriately serve as the chosen compositions in order to obtain an effective tool. The concepts of excluding features and generalized quantifiers will be employed in the constructed method as well. Some interesting properties will be introduced and a real example of the influence of the new concept will be provided.

Compositions of partial fuzzy relation

Nhung Cao and Martin Štěpnička

The aim of this contribution is to study compositions of partial fuzzy relational compositions, i.e., of fuzzy relations with membership degrees not defined on the whole universe. This is motivated by the possibility of existence of the relationships which are "undefined", "unknown", "meaningless", "non-applicable", "irrelevant", etc. We introduce definitions for the new concept based on suitable operations used in the framework of the partial fuzzy set theory. The preservations of well-known interesting properties of compositions are studied for the compositions of partial fuzzy relations as well. An illustrative example is provided.

Towards a hierarchical extension of contextual bipolar queries

Janusz Kacprzyk and Sławomir Zadrożny

We are concerned with the bipolar database queries in which the query is composed of a necessary (required) and optional (desired) part connected with a non-conventional aggregation operator "and possibly", combined with context, as, for instance, in the query "find houses which are cheap and – with respect to other houses in town – possibly close to a railroad station". We deal with a multivalued logic based interpretation of bipolar queries. We assume that the human user, usually a database novice, tends to use general terms in the queries in natural language, which do not directly relate to attributes, and via a question and answer process these terms are "decoded" using a concept hierarchy that at the end involves terms directly related to attribute values. We propose a novel extension of our contextual hierarchical bipolar database query in which the original query is considered a level 0 query at the bottom of the precisiation hierarchy, then its required and optional parts are assumed to be bipolar queries themselves, with an account of context. This makes it possible to further precisiate the user's intentions/preferences. A level 1 of precisiation is obtained, and the process is continued so far as it is necessary for the user to adequately reflect his/her intentions/preferences as to what is sought. The new concept is demonstrated on an intuitively appealing real estate example which will serve the role of both an illustration of the idea of our approach and of a real example.

Quantification over Undefined Truth Values

Martina Daňková

We will recall three prominent families of quantifiers in first-order partial fuzzy logic and study their properties. The background fuzzy logic is the monoidal

t-norm based logic MTL. First we will overview the semantics of partial fuzzy propositional logic, recall the basic notions, comment on axiomatization and present its first-order variant. Then we will present results on the properties of quantifiers from different families.

Predicting First-Episode Psychosis Associated with Cannabis Use with Artificial Neural Networks and Deep Learning

Daniel Stamate, Wajdi Alghamdi, Daniel Stahl, Ida Pu, Fionn Murtagh, Danielle Belgrave, Robin Murray and Marta di Forti

In recent years, a number of researches started to investigate the existence of links between cannabis use and psychotic disorder. More recently, artificial neural networks and in particular deep learning have set a revolutionary wave in pattern recognition and machine learning. This study proposes a novel machine learning approach based on neural network and deep learning algorithms, to developing highly accurate predictive models for the onset of first-episode psychosis. Our approach is based also on a novel methodology of optimising and post-processing the predictive models in a computationally intensive framework. A study of the trade-off between the volume of the data and the extent of uncertainty due to missing values, both of which influencing the predictive performance, enhanced this approach. Furthermore, we extended our approach by proposing and encapsulating a novel post-processing k-fold cross-testing method in order to further optimise, and test these models. The results show that the average accuracy in predicting first-episode psychosis achieved by our models in intensive Monte Carlo simulation, is about 89%.

Opinion mining in social networks for Algerian dialect

Mehdi Bettiche, Moncef Zakaria Mouffok and Chahnez Zakaria

There has been a significant increase in the volume of Arabic dialect messages on social networks, providing a rich source for opinion mining research. Most research works done on Arabic dialect focus on messages written in Arabic script, with very limited scope on Latin script. In this paper, we are interested in the classification of social networks messages retrieved from Twitter, Facebook and YouTube written in Algerian dialect in Latin script into positive or negative classes using existing opinion mining approaches (lexical-based, machine learning, and hybrid). Also, we apply a regrouping process in the preprocessing step to overcome the issues related to the Algerian dialect such as the orthographic varieties to express the same word. Furthermore, we focus on the hybrid approach which consists in automatically annotating the training corpus with the

lexical-based approach and then use the machine learning approach on this corpus for creating the classification model. This approach allows classifying the messages into positive or negative classes, without having to annotate manually a training corpus.

Representing Hypoexponential Distributions in Continuous Time Bayesian Networks

Manxia Liu, Fabio Stella, Arjen Hommersom and Peter J.F. Lucas

Continuous time Bayesian networks offer a compact representation for modeling structured stochastic processes that evolve over continuous time. In these models, the time duration that a variable stays in a state until a transition occurs is assumed to be exponentially distributed. In real-world scenarios, however, this assumption is rarely satisfied, in particular when describing more complex temporal processes. To relax this assumption, we propose an extension to support the modeling of the transitioning time as a hypoexponential distribution by introducing an additional hidden variable. Using such an approach, we also allow CTBNs to obtain *memory*, which is lacking in standard CTBNs. The parameter estimation in the proposed models is transformed into a learning task in their equivalent Markovian models.

Axiomatic of Inverse Lattice-valued F-transform

Jiří Močkoř

Axioms of two versions of inverse fuzzy transformation systems are introduced, and it is proved that a transformation function satisfies these axioms if and only if it is an upper or lower inverse lattice-valued F-transform with respect to a fuzzy partition. Categories of inverse transformation systems are introduced, and it is proved that these categories are isomorphic to the category of spaces with fuzzy partitions.

Why Triangular Membership Functions Are Often Efficient in F-Transform Applications: Relation to Probabilistic and Interval Uncertainty and to Haar Wavelets

Olga Kosheleva and Vladik Kreinovich

Fuzzy techniques describe expert opinions. At first glance, we would therefore expect that the more accurately the corresponding membership functions describe the expert's opinions, the better the corresponding results. In practice,

however, contrary to these expectations, the simplest – and not very accurate – triangular membership functions often work the best. In this paper, on the example of the use of membership functions in F-transform techniques, we provide a possible theoretical explanation for this surprising empirical phenomenon.

Enhanced F-transform exemplar based image inpainting

Pavel Vlašánek

This paper focuses on a completion of the partially damaged image. There are a variety of techniques to deal with this task. Our contribution belongs to the group of exemplar based image inpainting techniques which process the image what was separated to the many small regions. The regions are called patches and the task of inpainting becomes the task of searching for the most suitable patch from the undamaged part of the image to replace the partially damaged one. Our novelty is in processing based on fuzzy mathematics and new filling order prioritization function.

Missing data imputation by LOLIMOT and FSVM/FSVR algorithms with a novel approach: A Comparative Study

Fatemeh Fazlikhani, Pegah Motakefi and Mir Mohsen Pedram

Missing values occurrence is an inherent part of collecting data sets in real world's problems. This issue, causes lots of ambiguities in data analysis while processing data sets. Therefore, implementing methods which can handle missing data issues are critical in many fields, in order to providing accurate, efficient and valid analysis.

In this paper, we proposed a novel preprocessing approach that estimates and imputes missing values in datasets by using LOLIMOT and FSVM/FSVR algorithms, which are state-of-the-art algorithms. Classification accuracy, is a scale for comparing precision and efficiency of presented approach with some other well-known methods. Obtained results, show that proposed approach is the most accurate one.

Two Modifications of the Automatic Rule Base Synthesis for Fuzzy Control and Decision Making Systems

Yuriy P. Kondratenko, Oleksiy V. Kozlov and Oleksiy V. Korobko

This paper presents two modifications of the method of synthesis and optimization of rule bases (RB) of fuzzy systems (FS) for decision making and control of complex technical objects under conditions of uncertainty. To illustrate the advantages of the proposed method, the development of the RB of Mamdani type fuzzy controller (FC) for the automatic control system (ACS) of the reactor temperature of the experimental specialized pyrolysis plant (SPP) is carried out. The efficiency of the presented method of synthesis and optimization of the FS RB is investigated and its comparison with the other existing methods is carried out on the basis of this FC. Analysis of simulation results confirms the high efficiency of the proposed by the authors method of synthesis and reduction of the FS RB.

Decision making under incompleteness based on soft set theory

José Carlos R. Alcantud and Gustavo Santos-García

Decision making with complete and accurate information is ideal but infrequent. Unfortunately, in most cases the available information is vague, imprecise, uncertain or unknown. The theory of soft sets provides an appropriate framework for decision making that may be used to deal with uncertain decisions. The aim of this paper is to propose and analyze an effective algorithm for multiple attribute decision-making based on soft set theory in an incomplete information environment, when the distribution of incomplete data is unknown. This procedure provides an accurate solution through a combinatorial study of possible cases in the unknown data. Our theoretical development is complemented by practical examples that show the feasibility and implementability of this algorithm. Moreover, we review recent research on decision making from the standpoint of the theory of soft sets under incomplete information.

A Proposal for Adaptive Maps

Marina Torres, David A. Pelta and José L. Verdegay

The visualization of specific attributes of the maps is not achieved with standard maps representations or area cartograms. Adaptive Maps can deal with multiple attributes like travel time, quality of the road or tourism interest of the path between two points.

A method to generate and visualize Adaptive Maps is proposed. It departs from a graph with multiple attributes and generates a single measurement matrix that represent the desired distance between points. A Multidimensional Scaling problem on that matrix is solved to finally visualize the adapted map.

To illustrate the proposal, 4 adapted maps are generated and visualized.

Using inductive rule learning techniques to learn planning domains

José Á. Segura-Muros, Raúl Pérez and Juan Fernández-Olivares

When dealing with complex problems, designing a planning domain becomes a hard task that requires time and a skilled expert. This issue can be a problem when trying to model a planning domain intended to work in real-world applications. In order to overcome this problem, domain learning techniques are developed aiming to learn planning domains from existing real-world processes. Domain learning techniques then must face typical problems from this kind of applications such as data incompleteness. In this paper, we extend a classification algorithm developed by our research group, in order to create a highly resistant to incompleteness domain learner. We achieve this by extracting the information contained in a collection of plans and creating datasets, applying cleaning and preprocessing techniques to these datasets and then extracting the hypothesis that model the domain's actions using the classifier. Seeking a first validation of our solution before trying to work with real-world data we test it using a collection of simulated standard planning domains from the International Planning Competition. The results obtained shows that our approach can successfully learn planning actions even with a high degree of incompleteness.

Divergence Measures and Approximate Algorithms for Valuation Based Systems

Serafín Moral

This paper considers an abstract framework for expressing approximate inference algorithms in valuation based systems. It will provide a definition of a 'more informative' binary relation between representations of information as well as the basic properties of a divergence measure. The approach is illustrated with the cases of probabilistic reasoning (computation of marginal probabilities and most probable explanation) and with inference problems in propositional logic. Examples of divergence measures satisfying the basic properties will be given for these problems. Finally, we will formulate in an abstract way the mean field variational approach and the iterative belief propagation algorithm.

Evidential Bagging: Combining Heterogeneous Classifiers in the Belief Functions Framework

Nicolas Sutton-Charani, Abdelhak Imoussaten, Sébastien Harispe and Jacky Montmain

In machine learning, *Ensemble Learning* methodologies are known to improve predictive accuracy and robustness. They consist in the learning of many classifiers that produce outputs which are finally combined according to different techniques. *Bagging*, or Bootstrap Aggregating, is one of the most famous Ensemble methodologies and is usually applied to the same classification base algorithm, i.e. the same type of classifier is learnt multiple times on bootstrapped versions of the initial learning dataset. In this paper, we propose a *bagging* methodology that involves different types of classifier. Classifiers' probabilist outputs are used to build mass functions which are further combined within the belief functions framework. Three different ways of building mass functions are proposed; preliminary experiments on benchmark datasets showing the relevancy of the approach are presented.

Dealing with Epistemic Uncertainty in Multi-objective Optimization: A Survey

Oumayma Bahri and El-Ghazali Talbi

Multi-objective optimization under epistemic uncertainty is today present as an active research area reflecting reality of many practical applications. In this paper, we try to present and discuss relevant state-of-the-art related to multi-objective optimisation with uncertain-valued objective. In fact, we give an overview of approaches that have already been proposed in this context and limitations of each one of them. We also present recent researches developed for taking into account uncertainty in the Pareto optimality aspect.

Analyzing the Influence of LLVM Code Optimization Passes on Software Performance

Juan Carlos de la Torre, Patricia Ruiz, Bernabé Dorronsoro and Pedro L. Galindo

Sensitivity analysis is a mathematical tool that distributes the uncertainty of the output of a model among its different input variables. We use in this work the Extended Fourier Amplitude Sensitivity Test to carefully analyze the impact of 54 LLVM code optimization operators on the execution time of nine benchmark software programs. Experiments presented involve performing over 16 million executions. The results show that the different LLVM transformations have a low direct effect on the execution time, but it becomes meaningful

when considering the transformation in combination with the others (almost 60% average impact by all passes on all considered benchmarks). These results provide slight indications on the transformations to apply for optimizing the software, revealing the extreme difficulty of the problem.

A Novel Approach to The Discrete Fuzzy Transform of Higher Degree

Linh Nguyen and Michal Holčapek

In this paper, we propose a new approach to the discrete fuzzy transform of higher degree based on the piecewise constant representation of discrete functions and the application of the continuous fuzzy transform. We show how a given discrete function can be reconstructed by using the discrete higher degree fuzzy transform and how convenient the latter is computed by the novel approach. Finally, we illustrate and compare the proposed technique with the original discrete fuzzy transform of higher degree.

Lattice-Valued F-Transforms as Interior Operators of L-fuzzy Pretopological Spaces

Irina Perfilieva, S. P. Tiwari and Anand P. Singh

The focus is on two spaces with a weaker structure than that of a fuzzy topology. The first one is a fuzzy pretopological space, and the second one is a space with an L-fuzzy partition. For a fuzzy pretopological space, we prove that it can be determined by a Čech interior operator and that the latter can be represented by a reflexive fuzzy relation. For a space with an L-fuzzy partition, we show that a lattice-valued $F^{\downarrow}$-transform is a strong Čech-Alexandrov fuzzy interior operator. Conversely, we found conditions that guarantee that a given L-fuzzy pretopology determines the L-fuzzy partition and the corresponding $F^{\downarrow}$-transform operator.

Modified F-transform Based on B-splines

Martins Kokainis and Svetlana Asmuss

The aim of this paper is to improve the F-transform technique based on B-splines. A modification of the F-transform of higher degree with respect to fuzzy partitions based on B-splines is done to extend the good approximation properties from the interval where the Ruspini condition is fulfilled to the whole interval under consideration. The effect of the proposed modification is characterized theoretically and illustrated numerically.

Collocation method for linear BVPs via B-spline based fuzzy transform

Martins Kokainis and Svetlana Asmuss

The paper is devoted to an application of a modified F-transform technique based on B-splines in solving linear boundary value problems via the collocation method. An approximate solution is sought as a composite F-transform of a discrete function (which allows the solution to be compactly stored as the values of this discrete function). We demonstrate the effectiveness of the described technique with numerical examples, compare it with other methods and propose theoretical results on the order of approximation when the fuzzy partition is based on cubic B-splines.

Fuzzy relational compositions can be useful for customers credit scoring in financial industry

Soheyla Mirshahi and Nhung Cao

Fuzzy relational compositions is an important topic in fuzzy mathematics and many researchers have applied that in various fields which the classification problem was more and less accounted for the significant part. Related to this problem, in this paper, we will show that fuzzy relational compositions assist in evaluating customers creditability (credit scoring) which is one of the most important problems in the financial industry. The purpose is to classify a given customer into two classes of accepted or rejected and to help loan officers to make a better decision. We will illustrate an experimental example with initial values provided by an bank expert and use LFL R-package as the practical tool to calculate the compositions for our application. The concept of so-called generalized quantifiers and excluding features incorporating in the compositions will be employed as well.

Intelligent Decision Support System for Selecting the University-Industry Cooperation Model Using Modified Antecedent-Consequent Method

Yuriy Kondratenko, Galyna Kondratenko and Ievgen Sidenko

This work is devoted to the analysis and selection of the most rational model of the university/IT-company cooperation (UIC) using intelligent decision support systems (DSSs) in the conditions of input information uncertainty. The modification of a two-cascade method for reconfiguration of the fuzzy DSS's rule bases is described in details for situations when the volume of input data can be changed. Authors propose an additional observer procedure for checking

the fuzzy rule consequents before their final correction. The modified method provides (a) structural reduction of the rule antecedents, (b) correction of the corresponding consequents in an interactive mode and (c) avoiding the results' deformation in the decision making process with variable structure of input data. Special attention is paid to the hierarchically organized DSSs (with variable input vector and discrete logic output) and to design of the web-oriented instrumental tool (WOTFS-1). The simulation results confirm the efficiency and expediency of using (a) the software WOTFS-1 and (b) modified method of fuzzy rule base's antecedent-consequent reconfiguration for the efficient selection of the rational model of academia-industry cooperation.

Strategy to Managing Mixed Datasets with Missing Items

Inna Skarga-Bandurova, Tetiana Biloborodova and Yuriy Dyachenko

The paper refers to the problem of decision making and choosing appropriate ways for decreasing the level of input information uncertainty related to absence or unavailability some values of mixed data sets. Approaches to addressing missing data and evaluating their performance are discussed. The generalized strategy to managing data with missing values is proposed. The study based on real pregnancy-related records of 186 patients from 12 to 42 weeks of gestation. Three missing data techniques: complete ignoring, case deletion, and random forest (RF) missing data imputation were applied to the medical data of various types, under a missing completely at random assumption for solving classification task and softening the negative impact of input information uncertainty. The efficiency of approaches to deal with missingness was evaluated. Results demonstrated that case deletion and ignoring missing values were the less suitable to handle mixed types of missing data and suggested RF imputation as a useful approach for imputing complex pregnancy-related data sets with missing data.

Predicting Opponent Moves for Improving Hearthstone AI

Alexander Dockhorn, Max Frick, Ünal Akkay and Rudolf Kruse

Games pose many interesting questions for the development of artificial intelligence agents. Especially popular are methods that guide the decision-making process of an autonomous agent, which is tasked to play a certain game. In previous studies, the heuristic search method Monte Carlo Tree Search (MCTS) was successfully applied to a wide range of games. Results showed that this method can often reach playing capabilities on par with humans or even better. However, the characteristics of collectible card games such as the online

game Hearthstone make it infeasible to apply MCTS directly. Uncertainty in the opponent's hand cards, the card draw, and random card effects considerably restrict the simulation depth of MCTS. We show that knowledge gathered from a database of human replays help to overcome this problem by predicting multiple card distributions. Those predictions can be used to increase the simulation depth of MCTS. For this purpose, we calculate bigram-rates of frequently co-occurring cards to predict multiple sets of hand cards for our opponent. Those predictions can be used to create an ensemble of MCTS agents, which work under the assumption of differing card distributions and perform simulations according to their assigned distribution. The proposed ensemble approach outperforms other agents on the game Hearthstone, including various types of MCTS. Our case study shows that uncertainty can be handled effectively using predictions of sufficient accuracy, ultimately, improving the MCTS guided decision-making process. The resulting decision-making based on such an MCTS ensemble proved to be less prone to errors by uncertainty and opens up a new class of MCTS algorithms.

A New Generic Framework for Argumentation-based Negotiation using Case-Based Reasoning

Rihab Bouslama, Raouia Ayachi and Nahla Ben Amor

The growing use of Information Technology in automated negotiation leads to an urgent need to find alternatives to traditional protocols. New tools from fields such as Artificial Intelligence (AI) should be considered in the process of developing novel protocols, in order to make the negotiation process simpler, faster and more realistic. This paper proposes a new framework based on both argumentation and Case-Based Reasoning (CBR) as means of guiding the negotiation process to a settlement. This paper proposes a new generic domain-independent framework that overcomes the limits of domain-dependent frameworks. The proposed framework was tested in tourism domain using real data.

Personality determination of an individual through neural networks

J.R. Sánchez, Manuel Capel, Celina Jiménez, Gonzalo Rodríguez-Fraile and María del Carmen Pegalajar

The use of neural networks is proposed in this article as a means of determining the personality of an individual. This research work comes in view of the necessity of combining two psychological tests for carrying out personnel selection. From the assessment of the first test known as 16 Personality Factor we can

directly obtain an appraisal of the individual's personality type as the one given by the Enneagram Test, which now does not need to be done. The two chosen tests are highly accepted by Human Resources Department in big companies as useful tools for selecting personnel when new recruitment comes up, for personnel promotion internal to the firm, for employees' personal development and growing as a person. The (mathematical/computer science) model chosen to attain the research objectives is based on Artificial Neuron Networks.

On Dissimilarity Measures at the Fuzzy Partition Level

Grégory Smits, Olivier Pivert and Toan Ngoc Duong

On the one hand, a user vocabulary is often used by soft-computing-based approaches to generate a linguistic and subjective description of numerical and categorical data. On the other hand, knowledge extraction strategies (as e.g. association rules discovery or clustering) may be applied to help the user understand the inner structure of the data. To apply knowledge extraction techniques on subjective and linguistic rewritings of the data, one first has to address the question of defining a dedicated distance metric. Many knowledge extraction techniques indeed rely on the use of a distance metric, whose properties have a strong impact on the relevance of the extracted knowledge. In this paper, we propose a measure that computes the dissimilarity between two items rewritten according to a user vocabulary.

Fuzzy Extensions of Conceptual Structures of Comparison

Didier Dubois, Henri Prade and Agnès Rico

Comparing two items (objects, images) involves a set of relevant attributes whose values are compared. Such a comparison may be expressed in terms of different modalities such as identity, similarity, difference, opposition, analogy. Recently J.-Y. Béziau has proposed an "analogical hexagon" that organizes the relations linking these modalities. The hexagon structure extends the logical square of opposition invented in Aristotle time (in relation with the theory of syllogisms). The interest of these structures has been recently advocated in logic and in artificial intelligence. When non-Boolean attributes are involved, elementary comparisons may be a matter of degree. Moreover, attributes may not have the same importance. One might only consider *most* attributes rather than all of them, using operators such as ordered weighted min and max. The paper studies in which ways the logical hexagon structure may be preserved in such gradual extensions. As an illustration, we start with the hexagon of

equality and inequality due to Blanché and extend it with fuzzy equality and fuzzy inequality.

Monotonicity of a profile of rankings with ties

Raúl Pérez-Fernández, Irene Díaz, Susana Montes and Bernard De Baets

A common problem in social choice theory concerns the aggregation of the rankings expressed by several voters. Two different settings are often discussed depending on whether the aggregate is assumed to be a latent true ranking that voters try to identify or a compromise ranking that (partially) satisfies most of the voters. In a previous work, we introduced the notion of monotonicity of a profile of rankings and used it for statistically testing the existence of this latent true ranking. In this paper, we consider different extensions of this property to the case in which voters provide rankings with ties.

Consistency properties for fuzzy choice functions: an analysis with the Łukasiewicz t-norm

Susana Díaz, José Carlos R. Alcantud and Susana Montes

In continuation of the research in Alcantud and Díaz [1], we investigate the relationships between between consistency axioms in the framework of fuzzy choice functions. In order to help disclose the role of a t-norm in such analyses, we start to study the situation that arises when we use other t-norms instead. We conclude that unless we impose further structure on the domain of application for the choices, the use of the Łukasiewicz t-norm as a replacement for the minimum t-norm does not guarantee a better performance.

Entropy and Monotonicity

Bernadette Bouchon-Meunier and Christophe Marsala

Measuring the information provided by the observation of events has been a challenge for seventy years, since the simultaneous inception of entropy by Claude Shannon and Norbert Wiener in 1948. Various definitions have been proposed, depending on the context,the point of view and the chosen knowledge representation. We show here that one of the most important common feature in the choice of an entropy is its behavior with regard to the refinement of information and we analyse various definitions of monotonicity.

On the problem of comparing ordered ordinary fuzzy multisets

Ángel Riesgo, Pedro Alonso, Irene Díaz, Vladimír Janiš, Vladimír Kobza and Susana Montes

In this work we deal with a particular type of hesitant fuzzy set, in the case where membership values can appear multiple times and are ordered. They are called ordered ordinary fuzzy multisets. Some operations between them are introduced by means of an extension principle. In particular, the divergence measures between two of these multisets are defined and we have studied in detail the local family of divergences. Finally, these measures are related to the ones given for ordinary fuzzy sets.

Finding the most Influential Parameters of Coalitions in a PSO-CO Algorithm

Patricia Ruiz, Bernabé Dorronsoro, Juan Carlos de la Torre and Juan Carlos Burguillo

Literature reveals that optimization algorithms are generally composed of a large number of parameters that highly influence on its performance. In the early stages of the definition of a new algorithm, it is crucial to know how the uncertainty in the input parameters affects the behavior of the algorithm, influencing on its final output, so that it is possible to set up the most efficient configuration.

In this work, we are making a sensitivity analysis using the Extended Fourier Amplitude Sensitivity Test to compute the first order effects and interactions for each parameter on a recently proposed particle swarm optimization algorithm that implements a dynamic structured swarm, based on coalitions. This technique, inherited from game theory, includes four new parameters that are analyzed and tested on a well-known benchmark for continuous optimization. Results give interesting insights of the importance of one of the parameters over the rest.

A comparative analysis of accurate and robust bi-objective scheduling heuristics for datacenters

Sergio Nesmachnow and Bernabé Dorronsoro

This article presents and evaluates twenty-four novel biobjective efficient heuristics for the simultaneous optimization of makespan and robustness in the context of the static robust tasks mapping problem for datacenters. The experimental analysis compares the proposed methods over realistic problem scenarios. We

study their accuracy, as well as the regions of the search space they explore, by comparing versus state-of-the-art Pareto fronts, obtained with four different specialized versions of well-known multi-objective evolutionary algorithms.

Applying Genetic Algorithms for the Improvement of an Autonomous Fuzzy Driver for Simulated Car Racing

Mohammed Salem, Antonio Miguel Mora , Juan Julian Merelo and Pablo García-Sánchez

Games offer a suitable testbed where new methodologies and algorithms can be tested in a near-real life environment. For example, in a car driving game, using transfer learning or other techniques results can be generalized to autonomous driving environments. In this work, we use evolutionary algorithms to optimize a fuzzy autonomous driver for the open simulated car racing game TORCS. The Genetic Algorithm applied

improves the fuzzy systems to set an optimal target speed as well as the instantaneous steering angle during the race. Thus, the approach offer an automatic way to define the membership functions, instead of a manual or hill-climbing descent method. However, the main issue with this kind of algorithms is to define a proper fitness function that best delivers the obtained result, which is eventually to win as many races as possible. In this paper we define two different evaluation functions, and prove that fine-tuning the controller via evolutionary algorithms robustly finds good results and that, in many cases, they are able to play very competitively against other published results, with a more relying approach that needs very few parameters to tune. The optimized fuzzy-controllers (one per fitness) yield a very good performance, mainly in tracks that have many turning points, which are, in turn, the most difficult for any autonomous agent. Experimental results show that the enhanced controllers are very competitive with respect to the embedded TORCS drivers, and much more efficient in driving than the original fuzzy-controller.

A self-organizing ensemble of deep neural networks for the classification of data from complex processes

Niclas Ståhl, Göran Falkman, Gunnar Mathiason and Alexander Karlsson

We present a new self-organizing algorithm for classification of a data that combines and extends the strengths of several common machine learning algorithms, such as algorithms in self-organizing neural networks, ensemble methods and deep neural networks. The increased expression power is combined with the

explanation power of self-organizing networks. Our algorithm outperforms both deep neural networks and ensembles of deep neural networks. For our evaluation case, we use production monitoring data from a complex steel manufacturing process, where data is both high-dimensional and has many nonlinear interdependencies. In addition to the improved prediction score, the algorithm offers a new deep-learning based approach for how computational resources can be focused in data exploration, since the algorithm points out areas of the input space that are more challenging to learn.

Fuzzy rule learning for material classification from imprecise data

Arnaud Grivet Sébert and Jean-Philippe Poli

To address the problem of illicit substance detection at borders, we propose a complete method for explainable classification of materials. The classification is performed using imprecise chemical data, which is quite rare in the literature. We follow a two-step workflow based on fuzzy logic induction. Firstly, a clustering approach is used to learn the suitable fuzzy terms of the various linguistic variables. Secondly, we induce rules for a justified classification using a fuzzy decision tree. Both methods are adaptations from classic ones to the case of imprecise data. At the end of the paper, results on simulated data are presented in the expectation of real data.

Credal C4.5 with refinement of parameters

Carlos J. Mantas, Joaquín Abellán, Javier G. Castellano, José R. Cano and Serafín Moral-García

Recently, a classification method called Credal C4.5 (CC4.5) has been presented which combines imprecise probabilities and the C4.5 algorithm. The action of the CC4.5 algorithm depends on a parameter s. In previous works, it has been shown that this parameter has relation with the degree of overfitting of the model. The noise level of a data set can influence on the choice of a good value for s. In this paper, it is presented a new method based on the CC4.5 method with a refining of its parameter in the time of training. The new method has an equivalent performance than CC4.5 with the best value of s for each level noise.

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