

DETAILED PROGRAM

Monday, July 10, 8:00AM-10:00AM

Fuzzy Logic Control and Cognitive Systems-I

Monday, July 10, 8:00AM-10:00AM, Room: Normanna, Chair: Massimo Esposito

8:00AM *A framework for Culture-aware Robots based on Fuzzy Logic* [#585]

Barbara Bruno, Fulvio Mastrogiovanni, Federico Pecora, Antonio Sgorbissa and Alessandro Saffiotti, University of Genoa, Italy; Orebro University, Sweden

Cultural adaptation, i.e., the matching of a robot's behaviours to the cultural norms and preferences of its user, is a well known key requirement for the success of any assistive application. However, culture-dependent robot behaviours are often implicitly set by designers, thus not allowing for an easy and automatic adaptation to different cultures. This paper presents a method for the design of culture-aware robots, that can automatically adapt their behaviour to conform to a given culture. We propose a mapping from cultural factors to related parameters of robot behaviours which relies on linguistic variables to encode heterogeneous cultural factors in a uniform formalism, and on fuzzy rules to encode qualitative relations among multiple variables. We illustrate the approach in two practical case studies.

8:15AM *How Arithmically Fuzzy Are We? An Empirical Comparison of Human Imprecise Calculation and Fuzzy Arithmetic* [#384]

Sebastien Lefort, Marie-Jeanne Lesot, Elisabetta Zibetti, Charles Tijus and Marcin Detyniecki, LIP6, France; Laboratoire CHArt-LUTIN, France

This paper proposes an experimental comparison between human imprecise calculation and fuzzy arithmetic: an empirical study has been conducted to collect real intervals resulting from products and additions with imprecise operands from participants. Fuzzy intervals are elicited from these data and fuzzy arithmetic is applied to the collected imprecise operands. Comparisons show that the fuzzy product and addition differ from the way human beings perform these operations. Moreover, they show that the participants, rather than taking into account the imprecisions in the calculations, realise exact calculation and in the end approximate the exact result.

8:30AM *An Integrated Fuzzy Cognitive Map-Bayesian Network Model for Improving HSEE in Energy Sector* [#318]

Ali Azadeh, Pourreza Pooya, Saberi Morteza and Khadeer Hussain Omar, University of Tehran, Iran; UNSW Canberra, Australia

Health, Safety, Environment and Ergonomic (HSEE) are important factors in any organization. An organization always have to assess its compliance in these factors to the required benchmarks and take proactive actions to improve them if required. In this paper, we propose a Fuzzy Cognitive Map-Bayesian network (BN) model to identify the KPIs in HSEE measurement and management. Fuzzy Cognitive Map (FCM) method is used for constructing graphical model of BN to ascertain the relationships between the inputs and the impact that they will have on the quantified HSEE. After the KPIs are identified, Noisy-OR method and EM techniques are used to ascertain the conditional probability between the inputs to quantify the HSEE value. Using this, we find out the most influential input factor on HSEE quantification, which can then be managed for improving an organization's compliance to HSEE. Leveraging the power of Bayesian network in modeling

HSEE and augmenting it with FCM is the main contribution of this research work which opens this line of research.

8:45AM *Improved stability and stabilization criteria for T-S Fuzzy Systems with time-varying delay* [#16]

Chen Jian, Lin Chong and Chen Bing, Institute of Complexity Science, Qingdao University, China

This paper studies the problems of stability analysis and stabilization for a class of nonlinear systems represented by T-S fuzzy models with time-varying delay. Based on a reinforced Lyapunov-Krasovskii functional, a new delay-dependent criterion for ensuring the asymptotic stability of the concerned fuzzy systems has been derived in terms of linear matrix inequalities (LMI). Then, the state feedback control design is derived to achieve the stabilization. The efficiency and merits of the proposed approach are shown through several numerical examples.

9:00AM *Guaranteed Cost Adaptive Sliding Mode Fuzzy Control Systems* [#611]

Mojtaba Ahmadiéh khanesar and Meshkat Hosseini, Semnan University, Iran

In this paper, a novel sliding mode control technique is proposed which benefits from recursive least square adaptation laws. Since this method has high resistance against uncertainty and may result in a desirable transient response, this method is one of the most commonly used nonlinear control methods. In this method, the uncertain dynamics of system is stabilized by applying a discontinuous control signal. The principle of this type of controller is to force the states of the system towards sliding manifold and maintain the states of this stable manifold which defines the desired behavior of the system. It is possible to model dynamic behavior of physical systems in terms of fuzzy systems. In order to tune the parameters of fuzzy system, a cost function based on sliding mode is proposed. The solution to this cost function results in optimal adaptation laws whose stability analysis is done using an appropriate Lyapunov function. The proposed adaptive sliding mode fuzzy controller is simulated on an inverted pendulum to test its efficacy and performance in control of a benchmark system.

9:15AM *LMI-Based Fault Detection and Isolation of Nonlinear Descriptor Systems* [#522]

Francisco-Ronay Lopez-Estrada, Hector-Ricardo Hernandez-de-Leon, Victor Estrada-Manzo and Miguel Bernal, Instituto Tecnológico de Tuxtla Gutierrez, Mexico; Sonora Institute of Technology, Mexico

This paper develops conditions for sensor fault detection and isolation of nonlinear descriptor systems. The proposed methodology is based on a bank of observers, thus a novel approach is proposed to design Takagi-Sugeno observers in descriptor form. Traditionally, for descriptor systems, the designing conditions employ an augmented state vector whose elements are the state and its derivative. The proposed approach overcomes previous results in the literature by means of a novel augmented estimated vector, therefore conditions in terms linear matrix inequalities are directly obtained. The effectiveness of the given methodology is illustrated through a numerical example.

Soft Computing Methods for Eco-Efficiency

Monday, July 10, 8:00AM-10:00AM, Room: Sveva, Chair: Luciano Sánchez and José Ranilla

8:00AM *Energy-Aware Scheduling in Cloud Computing Systems* [#74]

Ivan Tomas Cotes-Ruiz, Rocio P. Prado, Sebastian Garcia-Galan and Jose Enrique Munoz-Exposito, Universidad de Jaen, Spain

The main objective of this work is to reduce power consumption and energy of a datacenter. There are various power saving techniques. A fuzzy system-based scheduler has been used, comparing its results with other well-known algorithms. The methods used in this paper are based on a combination of the DVFS algorithm and the development of a rule-based expert system to provide power-based planners for task planning domains. The parameters considered in the system are explained in detail and the results obtained are analyzed.

8:15AM *Evolved Frequency Log-Energy Coefficients for Voice Activity Detection in Hearing Aids* [#367]

Roberto Gil-Pita, Joaquin Garcia-Gomez, Marta Bautista-Duran, Elias Combarro and Alberto Cocana-Fernandez, University of Alcala, Spain; University of Oviedo, Spain

Eco-efficiency in hearing aids is an important issue, related to the maximization of the battery life. In order to minimize the power consumption, the embedded digital signal processor works at very low clock rates, constraining the implementation of signal processing techniques. The implemented algorithms can only use a small number of instructions per second and a small amount of memory. One of the main algorithms implemented in nowadays hearing aids is the voice activity detection algorithm, useful for several noise reduction and speech enhancement algorithms. The objective of this paper is the study of the implementation of voice activity detection algorithms in hearing aids using tailored fuzzy features, taking into account the optimization of the available resources.

8:30AM *Energy Efficient Scheduling on Heterogeneous Federated Clusters using a Fuzzy Multi-Objective Meta-heuristic* [#312]

Eloi Gabaldon, Sergi Vila, Fernando Guirado, Josep Lluís Lerida and Jordi Planes, Universitat de Lleida, Spain

Reducing energy consumption in large-scale computing facilities has become a major concern in recent years. The large number of computing nodes, resources heterogeneity and diversity of application requirements are factors that turn the scheduling into an NP-Hard problem. Evolutionary algorithms have proved to be effective for scheduling applications. In this paper, we present a novel approach combining particle swarm optimization and a genetic algorithm to solving the resource matching and scheduling of parallel applications in Federated cluster environments. The proposed hybrid meta-heuristic, referred to as MPSO-FGA, not only minimizes the overall energy consumption but also the makespan for a whole workload. The experimental results show the superiority of evolutionary algorithms over basic heuristics. The hybrid meta-heuristic is able to obtain similar results to a genetic algorithm in terms of energy consumption and makespan but reducing the time for scheduling decisions by two orders of magnitude.

8:45AM *Energy-Conscious Fuzzy Rule-based Classifiers for Battery Operated Embedded Devices* [#157]

Alberto Cocana, Jose Ranilla, Roberto Gil-Pita and Luciano Sanchez, Universidad de Oviedo, Spain; Universidad de Alcala, Spain

A fuzzy rule-based classifier is proposed in this paper where the number of rules in the knowledge base that are fired when an object is classified is anti-monotone with respect to the prior probability of its class. This classifier is intended to secure an equilibrium between accuracy and energy consumption, which is critical in battery operated embedded devices. The method is compared to legacy multi-criteria evolutionary algorithms, where a group of classifiers with different balances between accuracy and consumption are evolved, and the most accurate classifier is selected among those individuals in the Pareto front whose use of the battery does not exceed a given threshold. A significant increase in the battery life is reported without a degradation in the quality of service.

9:00AM *Prioritization of Load Points in Distribution System considering Multiple Load Types using Fuzzy Theory* [#234]

Hemakumar Reddy Galiveeti, Pranju Chakrapani, Arup Kumar Goswami and Nalini B Dev Choudhury, National Institute of Technology Silchar, India

The power shortages and/or outages in the distribution system enables the need of load shedding or curtailment, where the important loads are given high priority. This paper presents a novel method to solve the load point prioritization problem. The load points in the distribution system contains different types of loads and each load type has certain importance over other load type. The inclusion of load types in the load point ranking, increases the complexity in the problem. The proposed ranking method based on the fuzzy theory resolves this complexity and evaluates the weights of load points and thereupon ranking. The proposed method is validated on a test system considering a natural disaster situation.

9:15AM *Nonlinear Fuzzy P-Controllers for Active Power Balancing in Multi-Terminal DC Systems* [#203]

Sebastian Weck and Jutta Hanson, TU Darmstadt, E5, Germany

HVDC technology is a promising option to cope with regional power imbalances introduced by the increased generation from renewable energies. In particular, dc grids can be a technically and economically feasible solution for offshore and overlay applications. For dc grids, a concept for active power balancing has to be developed. This is usually done using piece-wise linear proportional control. This paper proposes a methodology for the design of nonlinear control characteristics using a fuzzy logic based P-controller. The controller is able to achieve a control characteristic with linear regions and smooth transitions, thus avoiding possible oscillations around the transition points. The controller is also able to handle security constraints using additional input variables.

Autonomous Control and Computational Intelligence for Security, Defence and Sensing Applications

Monday, July 10, 8:00AM-10:00AM, Room: Santa Lucia, Chair: Erdal KAYACAN

8:00AM *Fuzzy Financial Fraud Risk Governance System in an Information Technology Environment* [#366]

Marco P. L. Costa and Ernesto Araujo, Universidade Anhembi-Morumbi (UAM), Brazil

The financial fraud risk assessment requires expertise concerning the audit methodology and the risk assessment of business processes. The assessment of financial fraud risks is a significant challenge for independent, external auditors chiefly when dealing with the audit in an information technology (IT) environment. A meta-analysis financial fraud risk governance model taking into account an IT environment and based on fuzzy inference system is proposed in this paper. The fuzzy set theory and fuzzy logic are employed to deal with actual business audits, which do not always concern dichotomic fraud risk conditions. The inputs of the proposed fuzzy financial fraud risk governance system concern meta-analysis factors related to the fundamental domains of risk in IT audit. The input premise space comprises the effective identity and access protocol, system development, control of business operations, and change in systems or applications. Results demonstrate that the proposed approach enables supporting the operational risk management to promote the operational efficiency by identifying, measuring, and disclosing events (risk conditions) both in terms of qualitative (stratification) and quantitative (score) analysis. The fuzzy IT financial fraud risk system is able to work as a first barrier to reflect the adequacy of the information technologies and systems used to avoid risk in the financial fraud governance.

8:15AM *Biometric Hand Vein Estimation using Bloodstream Filtration and Fuzzy c-means* [#562]

Ondrej Krejcar and Lukas Kolda, University of Hradec Kralove, Czech Republic

Identification methods based on biometrics are going through great expansion lately. Therefore in this article we propose a realization of experimental multi-biometric system for laboratory verification of theoretical knowledge. The system identifies hand veins using biometric characteristics of hand contour and bloodstream on the dorsum of the hand. Moreover we alternatively put forward a fuzzy approach for segmentation of veins and estimation of the vein system by maximum curvature method.

8:30AM *An Efficient Fuzzy Path Selection Approach to Mitigate Selective Forwarding Attacks in Wireless Sensor Networks* [#254]

Seyyit Alper Sert, Carol Fung, Roy George and Adnan Yazici, Middle East Technical University, Turkey; Virginia Commonwealth University, United States; Clark Atlanta University, United States

Wireless Sensor Networks (WSNs) facilitate efficient data gathering requirements occurring in indoor and outdoor environments. A great deal of

WSNs operates by sensing the area-of-interest (AOI) and transmitting the obtained data to a sink(s). The transmitted data is then utilized in decision making processes. In this regard, security of raw and relayed data is both crucial and susceptible to malicious attempts targeting the task of the network which occurs on the wireless transmission medium. A node, when compromised, may deliberately forward data packets selectively. When this happens, nodes adjacent to the malicious nodes cannot identify the malevolent node and mitigate the effects of the attacks. In this study, we introduce a fuzzy path selection approach that efficiently mitigates single selective forwarding attacks in WSNs. Performance of our proposed approach and its evaluations are simulated and obtained. Our experimental results show that our approach is an effective solution to serve as a defense mechanism in terms of the efficiency metrics, such as Half of the Nodes Alive (HNA), Total Remaining Energy (TRE), and Packet Drop Ratio (PDR).

8:45AM *Air Combat Learning from F-16 Flight Information* [#360]

Mustafa Karli, Mehmet Onder Efe and Hayri Sever, Hacettepe University, Turkey

Movement sequence of a real air combat flight contains valuable information that can be used to infer artificial air combat learning. There are different ways to control unmanned aerial vehicles for a given flight path. But identifying the best move at the time being relative to an enemy air craft requires learning flight experience from real air combat fighters. This paper shows how to set up learning and control environment with adaptive neuro fuzzy inference system for maneuver decisions using real F-16 flight information. Real flight information is also utilized to justify the test results.

9:00AM *Takagi-Sugeno Fuzzy Controller Structures for Twin Rotor Aerodynamic Systems* [#28]

Raul-Cristian Roman, Radu-Emil Precup, Mircea-Bogdan Radac and Emil M. Petriu, Politehnica University of Timisoara, Romania; University of Ottawa, Canada

This paper proposes structures of Takagi-Sugeno fuzzy (TSF) controllers along with approaches to design these structures dedicated to the azimuth and pitch position control of twin rotor aerodynamic systems (TRASs). The azimuth and the pitch positions are separately controlled using Single Input-Single Output (SISO) control system structures. Two Proportional-Integral-Derivative (PID) TSF controllers are suggested for azimuth position control, and they are build around linear PID controller structures. A PI and a PID TSF controller are suggested for pitch position control by fuzzifying the linear PI and PID controller structures. The validation of the new TFS controllers is carried out on nonlinear TRAS laboratory equipment. The performance of the SISO control systems with the new TFS controllers is compared with two linear controllers tuned by a metaheuristic Gravitational Search Algorithm optimizer.

Fuzzy Logic and Computational Intelligence applications for Computer-Supported Collaborative Work

Monday, July 10, 8:00AM-10:00AM, Room: Aragonese, Chair: Ansol Pena-Rios, Anne Liret and George Panoutsos

8:00AM *A Fuzzy Logic Based System for Geolocated Augmented Reality Field Service Support* [#146]

Ansol Pena-Rios, Hani Hagra, Gilbert Owusu and Michael Gardner, University of Essex, United Kingdom; British Telecom, United Kingdom

In recent years, Augmented Reality (AR) started transitioning from an experimental technology to a more mature area, with new types of applications in entertainment, marketing, education, retail, transportation, manufacturing, construction, and other industries. One of the main challenges for AR-based field service tools is to help users to correctly locate

company's assets and infrastructure in the field. This paper presents an AR system using private maps to find company's assets to support field workforce tasks. The AR system is based on fuzzy logic mechanisms to provide the user with directions for asset location by comparing his/her current position with assets' location in real-time. Auditory and visual feedback is provided via a head mounted display (HMD), enhancing user's perception to achieve human augmentation.

8:15AM Adaptive Fuzzy Inference System Plug-in for Writer Adaptation [#266]

Lobna Haddad, Hamdani Tarek M. and Alimi Adel M., REGIM: REsearch Groups in Intelligent Machines, Tunisia

In this paper we proposed a writer adaptation system based on an adaptive fuzzy inference system (AFIS) that can be plug-in for any writer-independent handwriting recognition systems. The AFIS starts with an empty rule set. Subsequently, a supervised incremental learning algorithm is operated. When the user reports a misclassification, rule are added or updated. The proposed learning algorithm is evaluated by the adaptation of a writer-independent recognition system (LipiTk). Moreover, the results using a benchmark database named LaViola prove the efficiency of the proposed system. The error rate reduction varies between 66.32% and 41.05%.

8:30AM A combined Adaptive Neuro-Fuzzy and Bayesian strategy for recognition and prediction of gait events using wearable sensors [#105]

Uriel Martinez-Hernandez, Adrian Rubio-Solis, George Panoutsos and Abbas A. Dehghani-Sanij, University of Leeds, United Kingdom; University of Sheffield, United Kingdom

A robust strategy for recognition and prediction of gait events using wearable sensors is presented in this paper. The strategy adopted here uses a combination of two computational intelligence approaches: Adaptive Neuro-Fuzzy and Bayesian methods. Recognition of gait events is performed by a Bayesian method which iteratively accumulates evidence to reduce uncertainty from sensor measurements. Prediction of gait events is based on the observation of decisions and actions made over time by our perception system. An Adaptive Neuro-Fuzzy system evaluates the reliability of predictions, learns a weighting parameter and controls the amount of predicted information to be used by our Bayesian method. Thus, this strategy ensures the achievement of better recognition and prediction performance in both accuracy and speed. The methods are validated with experiments for recognition and prediction of gait events with different walking activities, using data from wearable sensors attached to lower limbs of participants. Overall, results show the benefits of our combined Adaptive Neuro-Fuzzy and Bayesian strategy to achieve fast and accurate decisions, but also to evaluate and adapt its own performance, making it suitable for the development of intelligent assistive and rehabilitation robots.

8:45AM Human and Dog Movement Recognition Using Fuzzy Inference System with Automatically Generated Membership Functions [#616]

Chukit Ruanpeng, Sansanee Auephanwiriyaikul and Nipon Theera-Umpon, Computer Engineering Dept., Faculty of Engineering, Chiang Mai University, Thailand; Electrical Engineering Dept., Faculty of Engineering, Chiang Mai University, Thailand

In this paper, the simple movement (walking dog, crawling human, and walking human) recognition system using the Mamdani fuzzy inference system is introduced. The membership functions of each input feature are generated automatically without experts' prior knowledges. The system produces a very high recognition rate, i.e., 93.97%, on the validation set of the cross validation. However, there are some misclassifications between walking dog and crawling human classes. The misclassifications are mainly from the incomplete segmentation of the objects of interest.

9:00AM A Fuzzy Approach to Qualification in Design Exploration for Robots and Autonomous Systems [#118]

Jeremy Morse, Dejanira Araiza-Illan, Jonathan Lawry, Arthur Richards and Kerstin Eder, University of Bristol, United Kingdom

Autonomous robots must operate in complex and changing environments subject to requirements on their behaviour. Verifying absolute satisfaction (true or false) of these requirements is challenging. Instead, we analyse requirements that admit flexible degrees of satisfaction. We analyse vague requirements using fuzzy logic, and probabilistic requirements using model checking. The resulting analysis method provides a partial ordering of system designs, identifying trade-offs between different requirements in terms of the degrees to which they are satisfied. A case study involving a home care robot interacting with a human is used to demonstrate the approach.

9:15AM Leveraging Uncertainty Modeling for Suspicious Tweets Detection [#547]

Mohamed Quafafou, Meryem Bendella and Saad Mekkaoui, Aix-Marseille University, France

Analyzing information from microblogs like Twitter is an important issue for the modern society that confronts new challenges. Its Security is the most crucial problem that requires one to anticipate different events, to track specific information or given persons. The detection of suspicious tweets is a main task in this issue, however tweets are generally not well written, contaminated by errors and may use metaphors, slang terms, and colloquialisms. Probabilistic methods inherited from information retrieval are systematically applied to social data analysis. In this paper, we combine probability theory and fuzzy logic in a harmonious approach, where the first one is more related to frequencies, whereas the second concerns qualitative modeling of suspicion and normality. The experimental results shows that the algorithm leveraging probability and fuzziness outperform the one based only on probability.

Mathematical and Theoretical Foundations of Fuzzy sets and Systems

Monday, July 10, 8:00AM-10:00AM, Room: Catalana, Chair: Stefano Aguzzoli

8:00AM Categories of Fuzzy Type Automata in Monads [#17]

Jiri Mockor, Ostrava University, Czech Republic

A category of fuzzy type automata in monads (in clone form) is introduced. A monad of extensional fuzzy sets in sets with similarity relations and a monad of fuzzy objects in spaces with fuzzy partitions are introduced and relationships between fuzzy automata in sets with similarity relation or in spaces with fuzzy partitions, on one hand, and fuzzy type automata in corresponding monads, on the other, are investigated.

8:15AM An Approximation of Fuzzy Numbers Based on Polynomial Form Fuzzy Numbers [#341]

Shahab Yeganehmanesh and Majid Amirfakhrian, IAUCTB, Iran

In this paper, we approximate an arbitrary fuzzy number by a polynomial fuzzy number through minimizing the distance between them. Throughout this work, we used a distance that is a meter on the set of all fuzzy numbers with continuous left and right spread functions. To support our claims

analytically, we have proven some theorems and given supplementary corollaries.

8:30AM *Numerical solution of partial differential equations with the help of fuzzy transform technique* [#570]

Michal Holcapek and Radek Valasek, University of Ostrava, Czech Republic

In this paper, we propose a numerical method based on the F-transform for an approximate solution of a certain type of partial differential equations with Dirichlet boundary conditions and initial conditions. The F-transform is an efficient method for the approximation of multivariate functions, where a transformation of a space of locally square integrable functions into a simple vector space of F-transform components is used. The F-transform is based on a fuzzy partition of the domain of multivariate functions. We show how the partial differential equations after the application of the Crank-Nicolson scheme for time discretization can be approximated by a system of linear equations with the direct F-transform components as their variables. Then, we derive elements of matrices using them the system of linear equations can be simply formulated. The F-transform components are then obtained as solutions of this system. The numerical solution of partial differential equations is a function which is found by the inverse F-transform. This function approximates the analytical solution, if there exists, with respect to the boundary and initial conditions. The proposed numerical method is concretely adjusted to the 2-dimensional boundary value problem, which is then used for solving two examples of partial differential equations, where one is artificial and the second one is real, namely, the Black-Scholes equation well-known in financial modeling.

8:45AM *Fixpoints of Fuzzy Closure Operators via Ordinary Algorithms* [#467]

Radim Belohlavek and Jan Konecny, Palacky University, Olomouc, Czech Republic

We present a way to compute the set of fixpoints of a given fuzzy closure operator via algorithms for computing sets of fixpoints of ordinary closure operators. We assume that the fuzzy closure operator is given by a set of fuzzy sets generating this operator. The proposed way is based on certain reduction theorems which we provide and which relate fuzzy and ordinary closure operators and the sets of their fixpoints. We also present explicit description of selected algorithms which result using the presented approach.

DM I: Fuzzy Decision Making

Monday, July 10, 8:00AM-10:00AM, Room: Giardino, Chair: Enrique Herrera-Viedma Yucheng Dong

8:00AM *Multi-observer Decision Making Approach Using Power Fuzzy Soft Sets* [#250]

Sofiane Bouznad, Faouzi Sebbak, Farid Benhammadi, Yacine Amirat and Abdelghani Chibani, LISSI Laboratory, UPEC, France; Ecole Militaire Polytechnique (EMP), Algeria

In the present paper, a method based on a new concept called power fuzzy soft set is proposed for multi-observer decision making problems under uncertain information. The new method applies a weighted conjunctive operator to aggregate these sets into a reliable resultant power fuzzy soft set from the input data set. To decide among the alternatives, a new ranking algorithm is introduced. The effectiveness and feasibility of this method are demonstrated by comparing it to algorithms based on the maximum score in decision making.

9:00AM *Towards Relational Fuzzy Adjunctions* [#469]

Inma Cabrera, Pablo Cordero and Manuel Ojeda-Aciego, Universidad de Malaga, Spain

The problem of studying the existence of a right adjoint to a mapping defined between sets with different fuzzy structure naturally leads to the search of new notions of adjunction which fit better with the underlying structure of domain and codomain. In this work, we introduce a version of relational fuzzy adjunction between fuzzy preposets which generalizes previous approaches in that its components are fuzzy relations. We also prove that the construction behaves properly with respect to the formation of quotient with respect to the symmetric kernel relation and, thus, giving rise to a relational fuzzy adjunction between fuzzy posets.

9:15AM *Novel Similarity Measure for Interval-Valued Data Based on Overlapping Ratio* [#371]

Shaily Kabir, Christian Wagner, Timothy C. Havens, Derek T. Anderson and Uwe Aickelin, Intelligent Modelling and Analysis (IMA) Group and Lab for Uncertainty in Data and Decision Making (LUCID), School of Computer Science, University of Nottingham, Nottingham, United Kingdom; Department of Electrical and Computer Engineering, Michigan Technological University, Houghton, MI, United States; Department of Electrical and Computer Engineering, Mississippi State University, Mississippi State, United States

In computing the similarity of intervals, current similarity measures such as the commonly used Jaccard and Dice measures are at times not sensitive to changes in the width of intervals, producing equal similarities for substantially different pairs of intervals. To address this, we propose a new similarity measure that uses a bi-directional approach to determine interval similarity. For each direction, the overlapping ratio of the given interval in a pair with the other interval is used as a measure of uni-directional similarity. We show that the proposed measure satisfies all common properties of a similarity measure, while also being invariant in respect to multiplication of the interval endpoints and exhibiting linear growth in respect to linearly increasing overlap. Further, we compare the behavior of the proposed measure with the highly popular Jaccard and Dice similarity measures, highlighting that the proposed approach is more sensitive to changes in interval widths. Finally, we show that the proposed similarity is bounded by the Jaccard and the Dice similarity, thus providing a reliable alternative.

8:15AM *Estimating Fuzzy Weight Vector from Interval Pairwise Comparison matrix with Various Processed Matrices* [#343]

Tomoe Entani, University of Hyogo, Japan

In this paper, the approach to estimate a fuzzy weight vector from an interval comparison matrix is proposed. The interval comparison allows a decision maker to state his/her uncertain judgment as a range, instead of a crisp value. By increasing and decreasing its upper and lower bounds of the interval comparison by the inverse rates, the processed comparison matrices are derived from the given matrix. The membership function of the fuzzy weight is based on the certainty degrees of the interval weight vectors obtained from the processed matrices. The interval weight vector is defined as a closure of the normalized crisp weight vectors each of which is included in an interval comparison matrix. Its certainty degree is represented as the sum of the lower bounds of all the corresponding interval weights.

8:30AM *Decision Making Problem Solving using Fuzzy Networks with Rule Base Aggregation* [#72]

Abdul Malek Yaakob, Alexander Gegov and Siti Fatimah Abdul Rahman, Universiti Utara Malaysia, Malaysia; University of Portsmouth, United Kingdom; Universiti Teknologi MARA, Malaysia

This paper introduces a novel extension of the Technique for Ordering of Preference by Similarity to Ideal Solution (TOPSIS) method. The method is based on aggregation of rules with different linguistic of the output of fuzzy networks to solve multi criteria decision-making problems whereby both benefit and cost criteria are presented as subsystems. Thus the decision maker evaluates the performance of each alternative for decision process and further observes the performance for both benefit and cost criteria. The aggregation of rule base in a fuzzy system maps the fuzzy membership functions for all rules to an aggregated fuzzy membership function representing the overall output for the rules. This approach improves significantly the transparency of the TOPSIS methods, while ensuring high effectiveness in comparison to established approaches. To ensure practicality and effectiveness, the proposed method is further tested on equity selection problems. The ranking produced by the method is comparatively validated using Spearman rho rank correlation. The results show that the proposed method outperforms the existing TOPSIS approaches in term of ranking performance.

8:45AM *Knowledge-based Consistency Index for Fuzzy Pairwise Comparison Matrices* [#12]

Sylvain Kubler, William Derigent, Alexandre Voisin, Jeremy Robert and Yves Le Traon, University of Luxembourg, Luxembourg; University of Lorraine, France

Fuzzy AHP is today one of the most used Multiple Criteria Decision-Making (MCDM) techniques. The main argument to introduce fuzzy set theory within AHP lies in its ability to handle uncertainty and vagueness arising from

decision makers (when performing pairwise comparisons between a set of criteria/alternatives). As humans usually reason with granular information rather than precise one, such pairwise comparisons may contain some degree of inconsistency that needs to be properly tackled to guarantee the relevance of the result/ranking. Over the last decades, several consistency indexes designed for fuzzy pairwise comparison matrices (FPCMs) were proposed, as will be discussed in this article. However, for some decision theory specialists, it appears that most of these indexes fail to be properly "axiomatically" founded, thus leading to misleading results. To overcome this, a new index, referred to as KCI (Knowledge-based Consistency Index) is introduced in this paper, and later compared with an existing index that is axiomatically well founded. The comparison results show that (i) both indexes perform similarly from a consistency measurement perspective, but (ii) KCI contributes to significantly reduce the computation time, which can save expert's time in some MCDM problems.

9:00AM *Enhanced Fuzzy System for Student's Academic Evaluation using Linguistic Hedges* [#126]

Ibrahim A. Hameed, Norwegian University of Science and Technology (NTNU), Norway

In this study, the effect of concentration, intensification and dilation of three common linguistic hedges (LHs), namely, very, indeed, and more or less on the performance of a fuzzy system for evaluating student's academic evaluation is presented. A LH may be viewed as an operator that acts on a fuzzy set representing the meaning of its operand. As an example, the operator very acts on the fuzzy meaning of the term high grade to have a secondary meaning of very high grade. This property changes the shape of the fuzzy sets and hence the amount of overlap between adjacent sets. It, in turn, improves the meaning of the fuzzy rules and hence the accuracy of the proposed fuzzy evaluation systems. The proposed LHs based fuzzy evaluator systems are compared with a standard fuzzy sets based fuzzy evaluator system using an example drawn from literature. Empirical results of the example presented in this paper show that concentration and dilation effect of LHs is not significant compared to standard fuzzy sets.

Fuzzy Web Intelligence: Representation, Reasoning and Applications

Monday, July 10, 8:00AM-10:00AM, Room: Borbonica, Chair: Chang-Shing Lee, Trevor Martin, Giovanni Acampora Marek Reformat

8:00AM *FML-based Robotic Summarization Agent and Its Application* [#201]

Chang-Shing Lee, Mei-Hui Wang, Chang-Yong Wang, Nan Shuo and Naoyuki Kubota, National University of Tainan, Taiwan; Tokyo Metropolitan University, Japan

In this paper, we present a summarization agent based on Fuzzy Markup Language (FML) and its application for meeting schedule data analysis. The knowledge base and rule base of FML are constructed by referring the meeting schedule ontology of Research and Development (RD) office in National University of Tainan (NUTN) from Jan. 2011 to Jul. 2015. We propose an intelligent agent to retrieve the meeting activities of RD Office from open meeting schedule database of NUTN. There are three categories belonging to the RD meeting schedule ontology, including an International Affairs division, an Academic Development division, and an Industry-Academia Collaboration division. In addition, we apply the Natural Language Processing (NLP) open API for Chinese text mining and document preprocessing. Finally, the proposed FML- based summarization agent is combined with the human-friendly robot partner PALRO, produced by Fujisoft incorporated, to construct a meeting summarization robot agent. Experimental results show that the proposed agent can work effectively.

8:15AM *Inliers, Outliers and Fuzzy Prototypes of the User Profiles in a Scientific Metasearcher* [#507]

Jose Olivas and Horacio Kuna, Universidad de Catilla-La Mancha, Spain; Universidad Nacional de Misiones, Argentina

Inliers and Outliers are widely studied in the world of databases. In the early 80's, L. A. Zadeh proposed an interesting approach to the concept of 'prototype' which contrasts with the classical theories of prototypes from the field of cognitive psychology. This definition has not been used much in fuzzy scientific proposals. Metasearch engines are often designed and used for Information Retrieval tasks because they are cheap and easy to develop, as they get their results from multiple search engines. In this paper, a definition of Inliers and Outliers is presented and related to Zadeh's concept of fuzzy prototype: Inliers with the prototype of the borderline elements and Outliers with the prototype of the bad elements of a dataset. Then, this approach is used for dealing with the User Profiles in a real Scientific Metasearcher with the aim of proposing recommendations, sending warnings and in general enriching the management of these User Profiles. An example and experiments proposal in this real system are also presented.

8:30AM *Composition-based Users' Matching Processes with Pythagorean Fuzzy Sets* [#580]

Marek Z. Reformat and Ronald R. Yager, University of Alberta, Canada; Iona College, United States

A search process becomes an essential component of everyday routine for many users. Users constantly look for new, and more or less relevant items that they require for work or for entertainment. On multiple occasions, they try to find other users who match their 'likes' and 'dislikes'. Many different methods and approaches have been proposed and developed to address such needs. The Pythagorean Fuzzy Sets have been proposed as a new class of non-standard fuzzy sets. They are related to the idea of Pythagorean membership grades (a,b) that satisfy the requirement $a^2 + b^2 < 1$. The interesting aspect of those types of sets is their ability to express a positive support a - a positive membership grade, and a negative support b - a negative membership grade. In this paper, we propose a method based on the application of Pythagorean fuzzy relations for identifying a degree of matching between users based on their evaluations of items. We use triangular compositions to determine users that match positive evaluations, and users that agree on negative ones. The usage of Pythagorean fuzzy sets allows us to take into consideration both positive and negative aspects of evaluations and find users who like or dislike at least the same items as a given user likes or dislikes. The proposed approach is used to identify users that evaluate movies in a similar way.

8:45AM *Graded Concepts and Associations* [#582]

Trevor Martin and Ben Azvine, University of Bristol, United Kingdom; BT Research and Innovation, United Kingdom

In the current data-rich / knowledge-poor world, humans require machine assistance to summarize, analyze and understand a situation and the trends in events. The idea of collaborative intelligence enables humans to focus on higher-level tasks involving insight and understanding, whilst machines deal with gathering, filtering and processing data into a convenient and understandable form. In this paper, we propose graded concept lattices as a representation for exchanging information between machine and human in a collaborative intelligent system. Graded concepts allow summarization at multiple levels of discernibility (granularity). We present a novel incremental algorithm to find a graded concept lattice. The lattice can be used to identify associations in data at multiple levels of discernibility.

9:00AM *FML-based Linguistic Classification Agent for Social Media Application* [#595]

ChangShing Lee, Mei-Hui Wang, Shih-Ya Lai, Nan Shuo and Naoyuki Kubota, National University of Tainan, Taiwan; Tokyo Metropolitan University, Japan

Fuzzy Markup Language (FML) presented by IEEE Computational Intelligence Society (CIS) has been an IEEE Standard since May 2016. It is

an XML-based language for designer to easily construct the knowledge base and rule base of the developed fuzzy logic system. In this paper, we propose an FML-based linguistic classification agent and apply it to popular Chinese songs' classification in social media environment. In addition, the lyrics are retrieved from Youtube, Facebook or Google+, and then we adopt Natural Language Processing (NLP) mechanism to deal with the document preprocessing. First, the domain experts construct the classification ontology model and design related categories for the application domain. Moreover, the fuzzy concept sets are also adopted in the related categories. Then, the Chinese Knowledge Information Processing (CKIP) tool is utilized to deal with the Chinese documents of the songs. Finally, the FML-based knowledge base and rule base of the classification agent are constructed for inferring the related categories of the song. The Fujisoft robot PALRO receives the classified songs and plays the song for the desired users. Experimental results show the proposed classification agent can work correctly.

9:15AM *IOWA and Cross-ratio Uninorm operators as aggregation tools in sentiment analysis and ensemble methods* [#5]

Orestes Appel, Francisco Chiclana, Jenny Carter and Hamido Fujita, De Montfort University, Great Britain; Iwate Prefectural University, Japan

In the field of Sentiment Analysis, a number of different classifiers are utilised to attempt to establish the polarity of a given sentence. As such, there could be a need for aggregating the outputs of the algorithms involved in the classification effort. If the output of every classification algorithm resembles the opinion of an expert in the subject at hand, we are then in the presence of a group decisionmaking problem, which in turn translates into two subproblems: (a) defining the desired semantic of the aggregation of all opinions, and (b) applying the proper aggregation technique that can achieve the desired semantic chosen in (a). The objective of this article is twofold. Firstly, we present two specific aggregation semantics, namely fuzzy-majority and compensatory, which are based on Induced Ordered Weighted Averaging and Uninorm operators, respectively. Secondly, we show the power of these two techniques by applying them to an existing hybrid method for classification of sentiments at the sentence level. In this case, the proposed aggregation solutions act as a complement in order to improve the performance of the aforementioned hybrid method. In more general terms, the proposed solutions could be used in the creation of semantic-sensitive ensemble methods, instead of the more simple ensemble choices available today in commercial machine learning software offerings.

Fuzzy Methods and Data Mining I: Rules Learning

Monday, July 10, 8:00AM-10:00AM, Room: Auditorium, Chair: José Antonio Sanz Mikel Galar

8:00AM *A first approach towards a fuzzy decision tree for multilabel classification* [#214]

Ronaldo Prati, Francisco Charte and Francisco Herrera, Federal University of ABC, Brazil; University of Granada, Spain

This paper proposes a multilabel fuzzy decision tree classifier named MLFuzzDT. The algorithm uses generalized fuzzy entropy, aggregated over all labels, to choose the best attribute for growing the tree. The proposed algorithm also can generate leaves predicting partial label sets, which can incorporate to some degree the dependence among labels, as well as produce more interpretable models. An empirical analysis shows that, although the algorithm does not yet incorporate pruning nor fuzzy interval adjustment phases, it is competitive with other tree based approaches for

multilabel classification, with better performance in data sets having numerical features that can be fuzzified.

8:15AM *Multi-class Boosting with Fuzzy Decision Trees* [#275]

Marco Barsacchi, Alessio Bechini and Francesco Marcelloni, University of Florence, Italy; University of Pisa, Italy

Boosting is a simple and effective procedure that combines several weak learners with the aim of generating a strong classifier. Multi-class boosting has been only recently studied in the context of crisp classifiers, showing encouraging performances. In this paper, we propose FDT-Boost, a boosting approach shaped according to the multi-class SAMME-AdaBoost scheme, that employs size-constrained fuzzy binary decision trees as weak classifiers.

We test FDT-Boost on twenty-three classification benchmarks. By comparing our approach with FURIA, one of the most popular fuzzy classifiers, and with a fuzzy binary decision tree, we show that our approach is accurate, yet keeping low the model complexity in terms of total number of leaf nodes.

8:30AM *Analyzing the behavior of a CC-integral in a Fuzzy Rule-Based Classification System* [#292]

Giancarlo Lucca, Jose Sanz, Gracaliz Dimuro, Benjamin Bedregal, Javier Fernandez and Humberto Bustince, Universidad Publica de Navarra, Spain; Universidade Federal do Rio Grande, Brazil; Universidade Federal do Rio Grande do Norte Natal, Brazil

In a recent paper, it was introduced the concept of Choquet-like Copula-based integral (CC-integral for short). This kind of function extends the standard Choquet integral and generalizes it by copula functions. These functions were applied in the Fuzzy Reasoning Method (FRM) of a Fuzzy Rule- Based Classification System (FRBCS), presenting an example where the CC- integral based on the minimum t-norm had different behaviors according to the values being aggregated. Therefore, the resulting FRM is theoretically more flexible than those associated with classical aggregation functions like the maximum. In this work, we present a methodology to study the flexibility of the aggregation function used in the FRM. Specifically, we conduct an analysis of 3 different methods to aggregate values in the FRM, namely, the CC- integral based on the minimum t-norm, the standard Choquet integral and the maximum (classical FRM of the winning rule – WR). We prove that the CC- integral behaves in different ways according to the values to be aggregated, whereas the Choquet integral offers an averaging behavior and the WR presents an strict behavior, since it considers only the rule having the maximum compatibility with the example.

8:45AM *Acoustic Event Classification using Cauchy Non Negative Matrix Factorization and Fuzzy Rule based Classifier* [#298]

Achyut Mani Tripathi and Rashmi Dutta Baruah, Indian Institute Of Technology Guwahati, India

Identification of presence of target acoustic sound or event from the single channel mixture is a challenging task of automatic sound recognition system.

The Theory of Type-2 Fuzzy Sets and Systems-I

Monday, July 10, 8:00AM-10:00AM, Room: Partenope, Chair: Robert John and Josie McCulloch

8:00AM *Type Reduction Techniques for Two-dimensional Interval Type-2 Fuzzy Sets* [#539]

Vaibhav Saxena, Nikhil Yadala, Rishav Chourasia and Frank Chung-Hoon Rhee, Indian Institute of Technology Guwahati, India; Hanyang University, Korea (South)

In this paper, we address the issue of type reduction of multi-dimensional interval type-2 (IT2) fuzzy sets (FSs). We utilize the Kamik- Mendel (KM) algorithm to estimate the centroid boundary of a multi-dimensional footprint of uncertainty (FOU). We deal with two-dimensional (2-D) fuzzy sets as we can visualize the FOU using 3-D plots, thus making the illustration of the methods simple. However, the basic idea can be extended to multiple dimensions. We give a formal definition of the centroid boundary of a 2-D IT2 fuzzy membership function (FMF) and propose two methods for its estimation. The first method computes embedded type-1 (T1) FSs whose centroids constitute the centroid boundary. We obtain the embedded sets by producing slices of the domain using different sets of parallel planes and then apply the KM algorithm over each slice, to obtain "embedded-curves." For the second method, we approximate our first method by restricting embedded-curves to

be "embedded-lines" thus enhancing computational speed. These type reduction techniques can be applied to applications involving multi-dimensional centroid estimation such as, clustering, support vector estimation for dimensionality reduction, fuzzy logic controllers, to mention a few.

In presence of background detection and classification of target acoustic event becomes more difficult. Various methods have been proposed that extract features from spectrogram of sound and then extracted features are used with traditional non negative matrix factorization for separation of overlapping sound. In this paper, we propose an approach to separate and classify single channel acoustic events. The method combines Common Fate Transformation and Cauchy Non-negative Matrix Factorization for feature extraction and finally fuzzy rule based classifier is developed for classification. The proposed method, when applied to real data, gave high true positive rate. The method also gave better results in terms of true positive rate when compared to widely used support vector machine using same real data. Moreover, the proposed approach is fast and can be used for the efficient separation of acoustic events from overlapping sounds.

9:00AM *Fuzzy ID3 Algorithm On Linguistic Dataset By Using WABL Defuzzification Method* [#183]

Suzan Kantarci-Savas and Efendi Nasibov, Dokuz Eylul University, Turkey

In real life, most of information is presented with words. Also, classification is an important issue to make decisions in daily life. Fuzzy logic gives flexibility to handle the imprecise information for computing with words. And, linguistic variables can be defined by using triangular fuzzy numbers given as L-R fuzzy numbers. This study aims to provide a classification approach by using fuzzy ID3 algorithm for linguistic data. In this study, Weighted Averaging Based on Levels (WABL) method, fuzzy c-means, and fuzzy ID3 algorithm are combined. WABL method is used to obtain crisp data set. Then, fuzzy c-means (FCM) algorithm is performed to introduce the shape of the linguistic terms limits and to obtain each membership degree of each linguistic term defined for fuzzy variables in data sets. At last, Fuzzy ID3 algorithm is applied. The rules are generated and the reasoning is done by using Zadeh T-norm/conorm operators. Experimental study is performed on six well-known data sets (Iris, Wdcb, Phoneme, Ring, Sonar, and Pima). As a conclusion, we proposed a fuzzy decision tree classification methodology for linguistic datasets.

8:15AM *Zadeh's Separation Theorem to Calculate Operations on Type-2 Fuzzy Sets* [#533]

Hooman Tahayori and Alireza Sadeghian, Department of Computer Science, Engineering and IT, Shiraz University, Iran; Department of Computer Science, Ryerson University, Canada

Processing type-2 fuzzy sets is more demanding than processing interval type-2 fuzzy sets or type-1 fuzzy sets. In this paper we propose a method for calculating union and intersection operations using min t-norm and max t-conorm on general type-2 fuzzy sets. The proposed method is based on Zadeh's separation theorem and though is straightforward. The important feature of the algorithm is its simplicity and applicability on the type-2 fuzzy sets with convex membership grades.

8:30AM *Exploring the Use of Type-2 Fuzzy Sets in Multi-criteria Decision Making based on TOPSIS* [#450]

Elissa Nadia Madi, Jonathan Garibaldi and Christian Wagner, Lab for Uncertainty in Data and Decision Making (LUCID) and IMA Research Group, School of Computer Science, University of Nottingham, United Kingdom; Institute of Computing and Cybersystems (ICC), Michigan Technological University, United States

Multi-criteria decision making (MCDM) problems are a well known category of decision making problem that has received much attention in the literature, with a key approach being the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). While TOPSIS has been developed towards the use of Type-2 Fuzzy Sets (T2FS), to date, the additional information provided by T2FSs in TOPSIS has been largely ignored since the final output, the Closeness Coefficient (CC), has remained a crisp value. In this paper, we develop an alternative approach to T2 fuzzy TOPSIS, where the final CC values adopt an interval-valued form. We show in a series of systematically designed experiments, how increasing uncertainty in the T2 membership functions affects the interval-valued CC outputs. Specifically, we highlight the complex behaviour in terms of the relationship of the uncertainty levels and the outputs, including non-symmetric and non-linear growth in the CC intervals in response to linearly growing levels of uncertainty. As the first TOPSIS approach which provides an interval-valued output to capture output uncertainty, the proposed method is designed to reduce the loss of information and to maximize the benefit of using T2FSs. The initial results indicate substantial potential in the further development and exploration of the proposed and similar approaches and the paper highlights promising next steps.

8:45AM *Interval type-2 fuzzy sets for Enhanced Learning in Deep Belief Networks* [#407]

Amit k. Shukla, Taniya Seth and Pranab K. Muhuri, South Asian University, India

Restricted Boltzmann Machine (RBM) is a generative, stochastic neural network with two separate layers of hidden and visible units. Training data samples in RBM are usually corrupted by noise. RBM is not robust enough to handle such noises, which leads to uncertainty. In the literature, Fuzzy RBM (FRBM) has already been proposed for enhancing deep learning. In FRBM, the parameters of RBM are modelled as type-1 fuzzy numbers. However, there can be multiple sources of uncertainties such as noises in the data measurements, variations in the environment where they are deployed, etc. Such uncertainties cannot be modelled by type-1 fuzzy sets (T1 FS), since their membership values are themselves crisp in nature. On the other side,

IT2 FS can model higher order uncertainties with their fuzzy membership grades. So, we propose to use interval type-2 fuzzy sets (IT2 FS) to model uncertain parameters of RBMs in the learning stage. Since deep neural network (DNN) is pre-trained using stacked RBMs, modeling noises using IT2 FS would demonstrate high performance and low root mean square error (RMSE) while learning. Thus, we propose a new algorithm viz. Interval type-2 fuzzy set based approach for enhanced deep learning (IT2 FS-EDL) in which RBM parameters are modeled as type-2 fuzzy sets in the learning process. Numerical examples and experimentations have been demonstrated to present the suitability of our proposed approach.

9:00AM *Particle Swarm Optimization for Solving a Class of Type-1 and Type-2 Fuzzy Nonlinear Equations* [#143]

Sheriff Sadiqbacha, Saeed Jafarzadeh and Yiannis Ampatzidis, California State University of Bakersfield, United States

This paper proposes a modified particle swarm optimization (PSO) algorithm that can be used to solve a variety of fuzzy nonlinear equations, i.e. fuzzy polynomials and exponential equations. Fuzzy nonlinear equations are reduced to a number of interval nonlinear equations using alpha cuts. These equations are then sequentially solved using the proposed methodology. Finally, the membership functions of the fuzzy solutions are constructed using the interval results at each alpha cut. Unlike existing methods, the proposed algorithm does not impose any restriction on the fuzzy variables in the problem. It is designed to work for equations containing both positive and negative fuzzy sets and even for the cases when the support of the fuzzy sets extends across 0, which is a particularly problematic case.

9:15AM *New Fuzzy Similarity Measures: from Intuitionistic to Type-2 Fuzzy Sets* [#495]

Sahar Cherif, Nesrine Baklouti, Vaclav Snasel and Adel M. Alimi, REGIM-Lab.: REsearch Groups in Intelligent Machines\National Engineering School of Sfax Sfax, Tunisia, Tunisia; Departement of Computer Science Faculty of Electrical Engineering and Computer Science, Czech Republic

Fuzzy Similarity Measure (FSM) is one of the most used techniques for classification, pattern recognition or knowledge reduction. While many type-1 FSMs exist, few ones exist for type-2 fuzzy sets. In this paper, we introduce three similarity measures between Interval Type-2 Fuzzy Sets (IT-2 FSs) as an extension of some distance measures between Intuitionistic Fuzzy Sets (IFSs). Many definitions and properties are exposed in order to prove that the formulas presented are indeed similarity measures. Experimental results are presented, comparison with other existing type-2 FSMs is done and interpretation is given in order to satisfy FSM properties.

Monday, July 10, 2:00PM-4:00PM

Fuzzy Logic Control and Cognitive Systems-II

Monday, July 10, 2:00PM-4:00PM, Room: Normanna, Chair: Hao Ying

2:00PM *Output Regulation of Large-Scale T-S Fuzzy-Model-Based Decentralized Control Systems with Unknown Interconnection Terms* [#519]

Yong Hoon Jang, Han Sol Kim, Young Hoon Joo and Jin Bae Park, Yonsei University, Korea (South); Kunsan National University, Korea (South)

This paper considers a regulation problem of nonlinear large-scale systems. To do this, a Takagi-Sugen (T-S) fuzzy model is adopted for fuzzy modeling of the nonlinear large-scale systems, which has unknown interconnection terms. An output-feedback decentralized fuzzy controller with integral action

is employed to drive the system outputs to reach a reference value and minimize the steady-state error. Sufficient conditions for the output regulation are derived from Lyapunov stability and these are formulated in terms of linear matrix inequalities (LMI). Finally, a numerical simulation example is given to demonstrate the effectiveness of the proposed design procedures and regulation conditions.

2:15PM *Merging Fuzzy Observer-based State Estimation and Database Classification for Fault Detection and Diagnosis of an Actuated Seat* [#377]

Rabih Taleb, Lynda Seddiki, Kevin Guelton and Herman Akdag, LIASD, University of Paris 8, France; CReSTIC EA3804, University of Reims Champagne-Ardenne, France

This paper proposes an approach for Fault Detection and Diagnosis (FDD) of an actuation system for passengers seats in commercial aircrafts. The FDD is performed using classification algorithms. The supervised classification algorithms are usually based on data collected from the different sensors installed on a real system. Thus, to reduce the number of embedded sensors and so the costs of seat components in commercial aircrafts, a fuzzy Takagi-Sugeno (T-S) state observer is considered to estimate non-measured state variables in order to enrich the database used for the supervised classification process. From experimental measurements on a prototype of the actuated seat, the benefit of adding T-S observer-based estimations is illustrated through a comparison of the classification results obtained using databases without then with estimated data.

2:30PM *Local D-stabilization of Uncertain T-S Fuzzy Models via Fuzzy Lyapunov Functions* [#131]

Abdelmadjid Cherifi, Kevin Guelton and Laurent Arcese, CReSTIC EA3804, University of Reims Champagne-Ardenne, France

This paper deals with the non-quadratic robust D-stabilization of uncertain Takagi-Sugeno (T-S) fuzzy systems. By considering the D-stability concept, Linear Matrix Linearity (LMI) conditions are proposed for the design of non Parallel-Distributed-Compensation (non-PDC) controllers via non-quadratic Fuzzy Lyapunov Functions (FLF). These conditions allow local D-stabilization. Thus, a simple way is considered to estimate the domain of attraction (DA) of the designed closed-loop dynamics. The proposed result is illustrated through a numerical example.

2:45PM *Stability of Takagi-Sugeno fuzzy systems with time-delay: a non-quadratic functional approach* [#313]

Sara Angulo, David Vazquez, Raymundo Marquez and Miguel Bernal, Sonora Institute of Technology, Mexico

This work deals with the problem of stability analysis of time-delay nonlinear systems in a Takagi-Sugeno form. More relaxed delay-dependent conditions in terms of linear matrix inequalities are developed from a novel non-quadratic Lyapunov-Krasovskii functional. The proposed non-quadratic structure is a state-dependent convex one, which includes former

approaches as particular cases while avoiding dealing with the time derivatives of the model nonlinearities in the convex sum. Some examples are given to illustrate the effectiveness of the proposed approach when compared with former solutions.

3:00PM *Local Stabilization of T-S Fuzzy Discrete-Time Systems with Time-Varying Delay in the States and Saturating Actuators* [#106]

Luis Silva, Valter Leite and Eugenio Castelan, CEFET-MG, Brazil; UFSC, Brazil

In this paper, conditions for local stabilization of Takagi-Sugeno (T-S) fuzzy discrete-time systems with time-varying delay and saturating actuators are developed. These conditions are based on a fuzzy Lyapunov-Krasovskii (L-K) candidate function and on a sector condition. Thus, an estimate of the region of attraction is characterized by two sets: one to deal with the current state vector and the other set to handle the delayed state vectors. The delay is supposed to be time-varying and belongs to the interval $[1, d_{max}]$. Only the current state, x_k , and the state delayed by d_{max} samples are fed back through the fuzzy control law. Furthermore, we propose a convex optimization procedure to maximize the estimate of the region of attraction for closed-loop control system. Finally, we give a numerical example to illustrate the obtained results.

3:15PM *A Novel Approach to TSK Model Based Gesture Driven Robot Movement* [#567]

Sriparna Saha, Rimita Lahiri, Amit Konar, Anna Lekova and Atulya K. Nagar, Jadavpur University, India; Bulgarian Academy of Sciences, Sofia, Bulgaria, Bulgaria; Liverpool Hope University, United Kingdom, United Kingdom

This paper presents a novel fuzzy based approach to gesture driven human robot interaction. Now a day, gestures are considered to be the most effective communicative medium for remotely controlling a robot. In this work, the gestures are employed to instruct a Khepera II robot to move from a specific starting position to a goal position following a specific path. The main highlight is the determination of exact degree of rotation with proper application of acceleration and brake in order to reach the specified goal position without hitting the obstacles. A Takagi-Sugeno-Kang based fuzzy model with two antecedents (type-2 fuzzy sets) and one consequent (crisp value) has been employed to determine the angle of rotation. The performance of the proposed framework has been tested in terms of a number of parameters like accuracy, precision, error rate etc. And in each case, the formulated strategy has proved its worth.

Fuzzy Systems on Smart Grid

Monday, July 10, 2:00PM-4:00PM, Room: Sveva, Chair: Faa-Jeng Lin and Francesco Grimaccia

2:00PM *A Hybrid SARFIMA-FTS Model for Time Series Prediction in Smart Grids* [#63]

Cidiney Silva, Frederico Gadelha Guimaraes, Hossein Javedani Sadaei and Vitor Nazario Coelho, Universidade Federal de Minas Gerais, Brazil; Universidade Federal Fluminense, Brazil

The intensive use of electricity in life and modern society implies increasing demand and the need for increasingly high reliability. Smart Grids (SG) are the next technological breakthrough to be achieved for the generation, transmission and distribution of energy. Historically, it has been sought to automate each of these systems to perform main and ancillary services. Robust forecasting methodologies are essential for planning and operation of SG. However, SG data presents the characteristics of long memory time series, which are a kind of stationary processes in such a way that there is always a statistical long range dependency between the current value and

values in different times of the series. Motivated by this, we introduce a new hybrid model combining Seasonal Auto Regressive Fractionally Integrated Moving Average with high order Fuzzy Time Series (SARFIMA-FTS). We present comparative results of SARFIMA-FTS with other two methodologies solutions in microgrid data. The computational results show that the performance of the proposed SARFIMA-FTS method is quite competitive with other presented methods in literature using less parameters, hence it is an important tool for prediction in smart grids.

2:15PM *An optimized Microgrid Energy Management System based on FIS-MO-GA paradigm* [#90]

Stefano Leonori, Maurizio Paschero, Antonello Rizzi and Frattale Mascioli Fabio Massimo, Department of Information Engineering, Electronics and Telecommunications (DIET), University of Rome "La Sapienza", Italy

The efficient integration of Renewable Energy Sources (RES) in the actual electrical grid has gained recently a high attention in the smart grids (SGs) research topic. The evolution of existing electric distribution networks into SGs can be accomplished gradually and conveniently through the installation of local grid-connected Microgrids (MGs), usually installed nearby the RESs and provided by Energy Storage Systems (ESSs). Each MG is in charge to manage connected RES, assuring the local power demand, as well as the safety and stability of the electric grid. To this aim, the Energy Management System (EMS) must provide intelligent decision making in fixing both MG configuration and energy flows between each subsystem in real time, according to some objective functions. In this work, it is proposed a MG EMS based on a Fuzzy Inference System (FIS) optimized through a custom implementation of Multi Objective Genetic Algorithm (MO-GA). In particular, the EMS is based on a three inputs FIS and it has been designed in order to reduce the fluctuations of energy exchanged with the grid (i.e. the grid stress) and to maximize the energy auto-consumption by employing an efficient utilization of the ESS. Results show that it is possible to improve considerably the auto-consumption performance, and at the same time to reduce grid stress, improving peak shaving concerning the maximum power request from the main grid.

2:30PM *Low-Voltage Ride-Through Operation of Single-Stage PV System Using Recurrent Fuzzy Cerebellar Model Articulation Controller* [#44]

Faa-Jeng Lin and Kuang-Chin Lu, Dept. of Electrical Engineering, National Central University, Taiwan; Internet of Things Laboratory, Teleco. Labs., Chunghwa Telecom Co. Ltd., Taiwan

Advantages of the recurrent fuzzy cerebellar model articulation controller (RFCMAC) include local generalization capability, fast learning, simplicity of computation, and capability of solving dynamic problem. Normally, the tracking error and the derivative of the tracking error are fed into the controller to perform the control of command tracking. Firstly, in this study, a two-dimensional RFCMAC (2D-RFCMAC) is adopted to approach the command control of the active and reactive power for performing the low-voltage ride-through (LVRT) operation of a single-stage photovoltaic (PV) system. However, the 2D-RFCMAC requires larger memory due to the memory size increases exponentially with the number of inputs. Thus, a one-dimensional RFCMAC (1D-RFCMAC) with signed distance and input space repartition mechanisms is proposed to replace the 2D-RFCMAC to perform the LVRT operation of the single-stage PV system. The reduced input dimension and computation complexity make the 1D-RFCMAC more practical. Moreover, some experimental tests are presented to illustrate the effectiveness of the proposed controller. The results show that the control performance of the proposed 1D-RFCMAC is not only slightly better than 2D-RFCMAC but also has lower memory size and computation complexity.

2:45PM *Clustering-based Novelty Detection to Uncover Electricity Theft* [#248]

Joaquim Viegas and Susana Vieira, IDMEC, Instituto Superior Tecnico, Universidade de Lisboa, Lisbon, Portugal, Portugal

The roll out of electricity grid assets with advanced communications capabilities enables new ways to steal energy, such as false data attacks and remote meter disconnection. On the other hand, data communicated by these devices has the potential to improve utilities ability to combat fraud through computational intelligence techniques. We propose a clustering-based novelty detection scheme to uncover electricity theft. The scheme starts by extracting easily interpreted consumption indicators from data collected by smart meters. Fuzzy clustering is then used to capture the structure of the data that consists of indicators from benign consumers. The extracted clusters provide the basis for a distance-based novelty detection model to uncover abnormal data sent by consumers. The results for the developed use case show that the proposed scheme using Gustafson-Kessel fuzzy clustering best captures the behavior of consumers, achieving good performance with a low number of clusters, in comparison to euclidean distance-based hard and fuzzy C-means.

3:00PM *A Graph-Based Semi-Supervised Learning Approach Towards Household Energy Disaggregation* [#429]

Ding Li and Scott Dick, University of Alberta, Canada

Non-Intrusive Appliance Load Monitoring has drawn increasing attention in the last few years. Many existing studies that use machine learning for this problem assume that the analyst has access to the actual appliances states at every sample instant, whereas in fact collecting this information exposes consumers to severe privacy risks. It may, however, be possible to persuade consumers to provide brief samples of the operation of their home appliances as part of a "registration" process for smart metering (if appropriate financial incentives are offered). This labeled data would then be supplemented by a large volume of unlabeled data. Hence, we propose the use of semi-supervised learning for non-intrusive appliance load monitoring. Furthermore, based on our previous work, we model the simultaneous operation of multiple appliances via multi-label classification. Thus, our proposed approach employs semi-supervised multi-label classifiers for the monitoring task. Experiments on publicly-available dataset demonstrate our proposed method.

3:15PM *Design of Fuzzy Logic Controllers for Decentralized Voltage Regulation in Grid Connected Photovoltaic Systems* [#38]

Hafsa Qamar, Haleema Qamar and Alfredo Vaccaro, Dept. of Engineering University of Sannio, Pakistan; Dept. of Engineering University of Sannio, Italy

This paper outlines the potential role of Fuzzy Logic Control (FLC) for voltage-rise mitigation in power distribution networks in the presence of grid-connected photovoltaic (PV) systems. In particular, after analyzing the main performances of the traditional techniques currently adopted for voltage rise mitigation by reactive power compensation, a decentralized approach based on local fuzzy controllers is proposed to regulate the reactive power injected into the grid by the distributed PV systems. The proposed solution is based on a closed control loop, where the local voltage at the point of common coupling (PCC) is fed at input to the FLC to decide the amount of reactive power generated by the local PV systems. The results obtained on a realistic case study are presented and discussed in order to assess the benefits deriving by the application of the proposed approach.

Fuzzy Logic Systems for Brain Analysis and Brain- Computer Interface

Monday, July 10, 2:00PM-4:00PM, Room: Santa Lucia, Chair: Javier Andreu-Perez and CT Lin

2:00PM *Improved Estimation of Effective Brain Connectivity in Functional Neuroimaging Through Higher Order Fuzzy Cognitive Maps* [#136]

Mehrin Kiani, Javier Andreu-Perez and Elpiniki I. Papageorgiou, Imperial College London, United Kingdom; echnological Educational Institute (T.E.I.) of Central Greece, Greece

In this paper, a novel technique for the computation of effective brain connectivity in functional Near-Infrared Spectroscopy (fNIRS) data is presented. The estimation of effective brain connectivity using the proposed approach of higher order Fuzzy Cognitive Maps (FCMs), used in conjunction with Genetic Algorithm (GA), is shown to be more accurate. Owing to lack of dependency on human knowledge, the FCM-GA model becomes more robust to subjective beliefs of experts from various domains when establishing connectivity matrix. Furthermore, higher order FCMs are capable of assessing causal relations in historical data with variable time lag, g , therefore generating more accurate predictions for complex causal data such as fNIRS where the causality may not necessarily follow a first order dynamics. The computation model of higher order FCM-GA is shown to perform better than Granger Causality (GC) for estimating effective brain connectivity in synthetic fNIRS data at 95% significance level. The proposed approach is also tested on real fNIRS data, and shown to estimate the causal structure amongst region of interests (ROIs) with improved accuracy.

2:15PM *A P300-Based Interface for Smart Home Interaction through an ANFIS Ensemble* [#615]

David Achancaray, Christian Flores, Christian Fonseca and Javier Andreu-Perez, Pontifical Catholic University of Peru, Peru; University of Engineering and Technology, Peru; Imperial College London, United Kingdom

Adaptive neuro fuzzy inference systems (ANFIS) has been applied in brain computer interfaces (BCI) in different ways, mapping P300 to known wave or fusing information from EEG channels; these applications have obtained high accuracies greater than 85%. This work proposes an ANFIS ensemble classifier, where it decide its output by voting to detect P300 wave in a BCI that could be used for smart home interaction; using four channels in the positions P4, P7, O1, and O2. Five healthy subjects and three post-stroke patients have participated in this study, each participant performs 4 BCI sessions, and crossvalidation is applied to evaluate the classifier performance by session. The results of average accuracy were greater than 75% for all subjects, similar results were gotten for healthy subjects a post-stroke patients, but the better ANFIS ensemble classifiers for each subject have gotten accuracies greater than 80%. These results show the suitability of proposed classifier in this interactive application.

2:30PM *EEG Induced Working Memory Performance Analysis Using Inverse Fuzzy Relational Approach* [#433]

Lidia Ghosh, Amit Konar, Pratyusha Rakshit, Anca L. Ralescu and Atulya K. Nagar, Jadavpur University, India; Cincinnati University, United States; Liverpool Hope University, United Kingdom

The paper attempts to model human working memory using fuzzy relational equation with an aim to retrieve the relevant stored information in the memory from the partial input using the model. Psycho-physiological experiments have been developed to validate the model to match the model generated memory-response with the actual memory response using EEG signals acquired during memory encoding and recall phases. The fuzzy relational equation developed here represents brain connectivity in the fuzzy space between the encoding and the recall instances. The paper introduces a novel approach to compute inverse fuzzy relation with respect to max-min composition operator to determine the short-term memory information from the working memory, when the latter is stimulated with partial faces of people already encoded in the short-term memory. An error metric is defined to

measure the error amplitude between the model-predicted encoding pattern and the actual pattern encoded in the short-term memory. A small value in error indicates a good accuracy of the proposed working memory model, and thus can be used to discriminate people with brain-related diseases. Experiments undertaken reveal that the error metric could be used successfully to detect memory failures in five patients, two of which suffer from Parkinson, two from the early Alzheimer's disease and one from frontal lobe damage.

2:45PM *A Virtual Reality and Brain Computer Interface System for Upper Limb Rehabilitation of Post Stroke Patients* [#542]

David Achancaray, Kevin Acuna, Erick Carranza and Javier Andreu-Perez, Pontifical Catholic University of Peru, Peru; Imperial College London, United Kingdom

This work presents a brain computer interface (BCI) framework for upper limb rehabilitation of post stroke patients, combining BCI and virtual reality (VR) technology; a VR feedback is shown to the participants to achieve a greater activation of certain brain regions involved with the performing of upper limb motor task. This system uses an adaptive neuro-fuzzy inference system (ANFIS) classifier to discriminate between a motor task and rest condition, the first one classifies between extension and rest conditions; and the second one classifies between flexion and rest conditions. In the training stage, eight healthy subjects participated in the sessions, the best accuracies are 99.3% and 88.9%, as a result of cross-validation. Meanwhile, the best accuracy in online test is 89%. The methodology here presented can be straightforwardly employed as a rehabilitation system for brain repair in individuals with neurological diseases or brain injury.

3:00PM *Estimation of SSVEP-based EEG Complexity using Inherent Fuzzy Entropy* [#548]

Zehong Cao, Mukesh Prasad and Chin-Teng Lin, University of Technology Sydney, Australia

This study considers the dynamic changes of complexity feature by fuzzy entropy measurement and repetitive steady-state visual evoked potential (SSVEP) stimulus. Since brain complexity reflects the ability of the brain to adapt to changing situations, we suppose such adaptation is closely related to the habituation, a form of learning in which an organism decreases or increases to respond to a stimulus after repeated presentations. By a wearable electroencephalograph (EEG) with Fpz and Oz electrodes, EEG signals were collected from 20 healthy participants in one resting and five-times 15 Hz SSVEP sessions. Moreover, EEG complexity feature was extracted by multi-scale Inherent Fuzzy Entropy (IFE) algorithm, and relative complexity (RC) was defined the difference between resting and SSVEP. Our results showed the enhanced frontal and occipital RC was accompanied with increased stimulus times. Compared with the 1st SSVEP session, the RC was significantly higher than the 5th SSVEP session at frontal and occipital areas ($p < 0.05$). It suggested that brain has adapted to changes in stimulus influence, and possibly connected with the habituation. In conclusion, effective evaluation of IFE has a potential EEG signature of complexity in the SSEVP-based experiment.

3:15PM *Multiclass EEG Data Classification using Fuzzy Systems* [#550]

Thanh Nguyen, Imali Hettiarachchi, Abbas Khosravi, Syed Moshfeq Salaken, Asim Bhatti and Saeid Nahavandi, Deakin University, Australia

This paper presents an approach to analysis of multiclass EEG data obtained from the brain computer interface (BCI) applications. The proposed approach comprises two stages including feature extraction using the common spatial pattern (CSP) and classification using fuzzy logic systems (FLS). CSP is used to extract significant features that are then fed into FLS as inputs for classification. The metaheuristic population-based particle swarm optimization method is used to train parameters of the FLS. The multiclass motor imagery dataset IIa from the BCI competition IV is used for experiments to highlight the superiority of the proposed approach against competing methods, which include linear discriminant analysis, naive bayes,

k-nearest neighbour, ensemble learning AdaBoost and support vector machine. Results from experiments show the great accuracy of the combination of CSP and FLS. Therefore, the proposed approach can be

implemented effectively in the practical BCI systems, which would be helpful for people with impairments and rehabilitation.

Theoretical aspects of aggregation functions I

Monday, July 10, 2:00PM-4:00PM, Room: Catalana, Chair: Radko Mesiar, Javier Montero, Javier Fernández Humberto Bustince

2:00PM *Aggregation functions Recent results and trends. [#56]*

Radko Mesiar, STU in Bratislava, Slovakia

We recall and discuss some recent results and trends in the aggregation theory. In particular, we discuss several monotonicity issues, construction issues and generalization of considered scales issues.

2:15PM *Aggregation Functions Given by Polynomial Functions [#387]*

Sebastia Massanet, Juan Vicente Riera and Joan Torrens, University of the Balearic Islands, Spain

In this paper aggregation functions whose expressions are given by polynomial functions are investigated. A detailed study focused on binary polynomial aggregation functions of degree one and two is given not only in general, but also requiring some additional properties like idempotency, commutativity, associativity, one-side neutral (or absorbing) element and so on, leading to some families of binary polynomial aggregation functions. The results concerning polynomials of degree one are generalized to n -ary polynomial aggregation functions whereas, with respect to those of degree two, the commutative case is also generalized obtaining the characterization of all commutative n -ary polynomial aggregation functions of degree two in general and jointly with the idempotent property.

2:30PM *Logic Aggregators and Their Properties [#236]*

Jozo Dujmovic, San Francisco State University, United States

Logic aggregators are defined as graded aggregators that aggregate degrees of truth, suitability, preference, and fuzzy membership. In this paper we present necessary and sufficient logic aggregators. In particular, we study logic aggregators that generalize classical Boolean logic and model observable properties of human reasoning in the area of soft computing evaluation logic. This paper introduces restrictive conditions that logic aggregators must satisfy.

2:45PM *Natural n -Dimensional Fuzzy Negations for n -Dimensional t -Norms and t -Conorms [#189]*

Ivan Mezzomo, Benjamin Bedregal and Renata Reiser, Rural Federal University of SemiArid - UFERSA, Brazil; Federal University of Rio Grande do Norte - UFRN, Brazil; Federal University of Pelotas - UFPel, Brazil

n -dimensional fuzzy sets are an extension of fuzzy sets where the membership values are n -tuples of real numbers in the unit interval $[0,1]$ ordered in increasing order, called n -dimensional intervals. The set of n -dimensional intervals is denoted by $\text{Ln}([0,1])$. In the present paper, we consider the definitions and results obtained for n -dimensional fuzzy negations, applying these studies mainly on natural n -dimensional fuzzy negations for n -dimensional triangular norms and triangular conorms. Additionally, the conjugate obtained by action of an n -dimensional automorphism on an n -dimensional natural fuzzy negations for n -dimensional triangular norms and triangular conorms, provides a method to obtain other n -dimensional strong fuzzy negations, in which its properties on $\text{Ln}([0,1])$ are preserved.

3:00PM *Penalty Functions Constructed from QL Subsethood Measures [#380]*

Helida Santos, Benjamin Bedregal, Gracaliz Dimuro and Humberto Bustince, Universidade Federal do Rio Grande do Norte, Brazil; Universidade Federal do Rio Grande do Norte, Brazil; Universidade Federal do Rio Grande, Brazil; Universidad Publica de Navarra, Spain
Penalty functions are widely used to measure disagreement or consensus. On the other hand, subsethood measures have been applied in several areas. In this paper, we introduce a method for constructing penalty functions by means of QL fuzzy subsethood measures, introduced by Dimuro et al., which are built from QL-operations derived from tuples (O, G, N) , for overlap functions O , grouping functions G and fuzzy negations N .

DM II: Hesitant Fuzzy Linguistic Decision Making

Monday, July 10, 2:00PM-4:00PM, Room: Giardino, Chair: Yucheng Dong Luís Martínez

2:00PM *A Consensus Degree for Hesitant Fuzzy Linguistic Decision Making [#168]*

Jordi Montserrat-Adell, Nuria Agell, Monica Sanchez and Francisco Javier Ruiz, UPC-Barcelona Tech, Spain; ESADE- URL, Spain

This paper proposes a measure of consensus for group decision making in the hesitant fuzzy linguistic term sets framework. An extension of the set of hesitant fuzzy linguistic term sets is considered to capture differences among discordant assessments. The difference between a pair of disjoint assessments is given by a measure that takes into account the gap between them. The proposed measure of consensus is defined using this extension, and, as a result, we obtain more accurate values, i.e., the new measure is able to distinguish among group consensus levels that were indistinguishable according to existing measures of consensus. An illustrative example is provided to show the potential of the proposed consensus degree, the process of its computation and a comparison with an existing approach based on a similarity among decision makers.

2:15PM *A Decision Making model to evaluate the reputation in Social Networks using HFLTS [#211]*

Rosana Montes, Ana M. Sanchez, Pedro Villar and Francisco Herrera, University of Granada, Spain

We present Teranga Go!, a social network with a linguistic fuzzy model which deals with hesitant information as a practical application of decision making problems. It is defined to help members to select to whom interact based on collective information regarding real interactions with any user. In this way, we provide a tool intended to build trust among members of a sharing economy community given that is a major drawback from online transactions. As a workbench to run the linguistic decision making model, a web site and a mobile application for iOS and Android offer access to a carpooling service named Teranga Go! that seek to foster the mobility of international migration flows from Europe to Africa, based on concepts of collaborative economy and participatory consumption. The novelty of the site is the possibility of using hesitant linguistic expressions to assess a set of qualitative criteria and the use of the community members as the pool of experts. Unlike many multi

criteria decision making problems we do not rank alternatives, we just qualify them using the retrieved opinions, which target a given user, and collected over any interaction with this person along the time. Based on Computing with Words methodology where inputs are words and output are also words, we obtain from the model a linguistic value that is used to represent a karma property present in the user profile.

2:30PM *A hesitant fuzzy linguistic model for emergency decision making based on fuzzy TODIM method* [#252]

Liang Wang, Ying-Ming Wang, Rosa M. Rodriguez and Luis Martinez, Decision Science Institute, Fuzhou University; Department of Computer Science, University of Jaen, China; Decision Science Institute, Fuzhou University, China; Department of Computer Science and Artificial Intelligence, University of Granada, Spain; Department of Computer Science, University of Jaen, Spain

The importance of emergency decision making (EDM) has grown up in recent years because of the frequent occurrence of multiple emergency events (EEs) that have caused important social and economic losses. EDM plays a relevant role when it is necessary to mitigate property and lives losses and reducing the negative impacts on the social and environmental development. Real-world EDM problems are usually characterized by complexity, hard time constraints, lack of information and the impact of the psychological behaviors which makes it very challenging task for the decision maker. This characterization shows the need of dealing with different types of uncertainty and the managing of behaviors to face these problems. This contribution proposes a new emergency decision model that first, uses fuzzy linguistic information to model the subjective information elicited by the decision maker under uncertainty and also the modelling of his/her hesitancy for assessing his/her judgements by using hesitant fuzzy linguistic term sets. Second it integrates the decision maker's psychological behavior by using the prospect theory in a fuzzy based environment. Finally, an example of application of the decision model is carried out to show its validity and applicability.

Linguistic Summarization and Description of Data

Monday, July 10, 2:00PM-4:00PM, Room: Borbonica, Chair: Nicolas Marin, Anna Wilbik, Rui-Jorge Almeida Daniel Sanchez

2:00PM *Interactive Data Exploration on Top of Linguistic Summaries* [#32]

Gregory Smits, R. Ronald Yager and Olivier Pivert, IRISA / University of Rennes 1, France; Machine Intelligence Institute / IONA College, United States

Extracting useful and interpretable knowledge from raw data is a crucial issue that has been largely addressed by the data mining community especially. In this paper we provide an interactive data exploration approach that relies on two steps. First, a personalized linguistic summary of the data set concerned is built and displayed as a tag cloud. Then, exploration functionalities are provided on top of the summary to let the user discover interesting properties in the data as frequent/atypical/diversified associations between properties.

2:45PM *A Consensus Approach for Hesitant Fuzzy Linguistic Decision Information* [#99]

Cuiping Wei, Chengjun Hou and Zaiwu Gong, Yangzhou University, China; Nanjing University of Information Science and Technology, China

This paper aims to study the consensus approach for the decision making problems with hesitant fuzzy linguistic decision matrices. The distance measure is proposed for the hesitant fuzzy linguistic term sets. Then based on the distance among the individual decision matrices, the group consensus level and some other consensus levels are defined for the hesitant fuzzy decision matrices, and the consensus reaching process is introduced. The model gives the adjustment suggestions to make the information provided for the experts as much as possible, and is helpful for the experts to determinate the adjusted elements. Finally, a numerical example is used to illustrate the feasibility and practicability of the proposed consensus model.

3:00PM *A Consistency-driven Approach to Set Personalized Numerical Scales for Hesitant Fuzzy Linguistic Preference Relations* [#590]

Li Cong-Cong, Rodriguez Rosa M., Herrera Francisco, Martinez Luis and Dong Yucheng, Sichuan University; University of Granada, China; University of Granada, Spain; University of Jaen, Spain; Sichuan University, China

In decision making dealing with computing with words, the importance of the statement that words mean different things for different people has been highlighted. In this paper, we focus on personalizing numerical scales of linguistic terms in decision making with hesitant fuzzy linguistic preference relations (HFLPRs). First, an average consistency measure for HFLPRs is provided, and then an optimization-based model to personalize individual semantics via numerical scales is presented, aiming at maximizing the average consistency of HFLPRs. Numerical examples are used to illustrate the proposal.

2:15PM *An Empirical Approach for Modeling Fuzzy Geographical Descriptors* [#223]

Alejandro Ramos-Soto, Jose M. Alonso, EHUD Reiter, Kees van Deemter and Albert Gatt, Centro Singular de Investigacion en Tecnoloxias da Informacion (CITIUS), Universidade de Santiago de Compostela, Spain; Department of Computing Science, University of Aberdeen, Scotland; Institute of Linguistics, University of Malta, Malta

We present a novel heuristic approach that defines fuzzy geographical descriptors using data gathered from a survey with human subjects. The participants were asked to provide graphical interpretations of the descriptors "north" and "south" for the Galician region (Spain). Based on these interpretations, our approach builds fuzzy descriptors that are able to compute membership degrees for geographical locations. We evaluated our approach in terms of efficiency and precision. The fuzzy descriptors are meant to be used as the cornerstones of a geographical referring expression generation algorithm that is able to linguistically characterize geographical locations and regions. This work is also part of a general research effort that intends to establish a methodology which reunites the empirical studies traditionally practiced in data-to-text and the use of fuzzy sets to model imprecision and vagueness in words and expressions for text generation purposes.

2:30PM *Declarative Computational Perceptions Networks for Automatically Generating Excerpts in Computer Games by using Bousi Prolog* [#316]

Clemente Rubio-Manzano and Martin Pereira-Farina, University of the Bio-Bio, Chile; Centre for Argument Technology (ARG-tech) University of Dundee, Scotland

Recently, we have presented a new technology for improving player experience in Computer Games by using players behaviour analysis and linguistic descriptions. Here, we explain the details about its implementation which have not been presented in any work before. Our implementation is based on a declarative version of the concept of computational perception network whose implementation has been performed by means of a fuzzy linguistic logic programming language named Bousi Prolog. Our aim is to show the potentiality of this kind of programming language in order to implement computational perceptions in computer games.

2:45PM *Evaluation of Causal Sentences in Automated Summaries* [#453]

Cristina Puente, Augusto Villa-Monte, Laura Lanzarini, Alejandro Sobrino and Jose A. Olivas, Advanced Technical Faculty of Engineering ICAI, Pontifical Comillas University, Spain; III-LIDI, Faculty of Computer Science, National University of La Plata, Argentina; Faculty of Philosophy, University of Santiago de Compostela, Spain; Department of Information Technologies and Systems, University of Castilla-La Mancha, Spain

This paper presents an experiment to show the importance of causal sentences in summaries. Presumably, causal sentences hold relevant information and thus summaries should contain them. We perform an experiment to refute or validate this hypothesis. We have selected 28 medical documents to extract and analyze causal and conditional sentences from medical texts. Once retrieved, classic metrics are used to determine the

relevance of the causal content among all the sentences in the document and, so, to evaluate if they are important enough to make a better summary. Finally, a comparison table to explore the results is showed and some conclusions are outlined.

3:00PM *On Families of Bounded Specificity Measures* [#464]

Nicolas Marin, Gustavo Rivas-Gervilla, Daniel Sanchez and Ronald R. Yager, University of Granada, Spain; Iona College, NY, United States

In this paper we propose bounding conditions that characterize different families of specificity measures. The proposed conditions are associated to particular semantics that provide us with different criteria for choosing the most appropriate specificity measure for a certain use. In particular, we distinguish predicate-like measures, mostly useful for providing a fuzzy classification of fuzzy sets between specific and non-specific, and index-like measures, which are more appropriate for providing an order relation between fuzzy sets in terms of their specificity. An intermediate class of measures is also studied, where different bounds are associated to values of the cardinality of fuzzy sets for which specificity is expected to be 0.

3:15PM *Towards improved generation of linguistic summaries* [#588]

Anna Wilbik, Uzay Kaymak and Remco Dijkman, TU/e, Netherlands

Generation of linguistic summaries that are compact, short and relevant to the user remains an open challenge. In this paper, we propose a novel method for improving the generation of linguistic summaries inspired by the a-priori algorithm and the degree of appropriateness. The method generates all true summaries with related predicates in the summarizer, resulting in a small set of linguistic summaries, whose presentation to the user is compact. We tested our method on three real world data sets. The results indicate that our proposed approach is a good alternative to previous methods suggested for generating linguistic summaries.

Fuzzy Methods and Data Mining II

Monday, July 10, 2:00PM-4:00PM, Room: Auditorium, Chair: José Antonio Sanz Mikel Galar

2:00PM *On the Results and Observations of the Time Series Forecasting Competition CIF 2016* [#117]

Martin Stepnicka and Michal Burda, University of Ostrava, Czech Republic

The aim of this paper is to present the results of the competition of time series forecasting using soft computing methods that was organized within the IEEE World Congress on Computational Intelligence (IEEE WCCI) in 2016.

2:15PM *Compound bipolar queries: the case of data with a variable quality* [#599]

Janusz Kacprzyk and Slawomir Zadrozny, Systems Research Institute, Polish Academy of Sciences, Poland

We further develop our concept of a compound query (cf. Kacprzyk and Zadrozny, 2013) in which in a bipolar query comprising of a required and desired condition aggregated via a non-conventional operator corresponding to "and if possible" the particular required and desired conditions are by themselves queries with fuzzy linguistic quantifiers. We use our approach to the dealing with data quality (trustworthiness), originally developed for the queries with fuzzy linguistic quantifiers (cf. Kacprzyk and Zadrozny, 2015), employ it for the required and desired conditions (queries with fuzzy linguistic quantifiers), and then implant into the compound query, i.e. a bipolar query with the required and desired conditions being queries with fuzzy linguistic

quantifiers. A new conceptual quality, functionality and human consistency is therefore obtained.

2:30PM *Modeling Patients' Methylmalonic Acid Levels using Probabilistic Fuzzy Systems* [#608]

Rui Jorge Almeida, Saskia van Loon, Uzay Kaymak, Anna Wilbik, Volkher Scharnhorst and Arjen-Kars Boer, Department of Quantitative Economics, Maastricht University, BISS Institute, Netherlands; Catharina Hospital, Clinical Chemistry, Netherlands; School of Industrial Engineering, Eindhoven University of Technology, Netherlands; Catharina Hospital, Clinical Chemistry, Department of Biomedical Engineering, Eindhoven University of Technology, Netherlands

Vitamin B12 deficiency is a common disorder with severe impacts on hematological and neurological disorders. Identifying vitamin B12 deficiency is not straightforward since blood vitamin B12 levels are not representative for actual vitamin B12 status in tissue. Instead, methylmalonic acid (MMA) levels in the plasma are used as indicators of vitamin B12 deficiency. MMA concentrations increase starting from the early course of vitamin B12 deficiency but they may also be high regardless of vitamin B12 deficiency due to renal failure (measured by eGFR). In this paper we propose the use of probabilistic fuzzy systems (PFS) to explore the relationship between MMA

plasma levels with vitamin B12 and kidney function. We propose a PFS model for the analysis of overall MMA properties for all patients and also specific MMA properties for individual patients. We show that this PFS model leads to accurate MMA interval predictions. We further show that the proposed model can be used to assess a change in the eGFR level to a normal eGFR level, and its effect on the patient's MMA distribution.

2:45PM Multiple Kernel Fuzzy Discriminant Analysis for Hyperspectral Imaging Classification [#528]

Shan Zeng, Bai Jun, Jiang Liang and Kang Zhen, College of Mathematics and Computer Science Wuhan Polytechnic University, China; College of Mathematics and Computer Science Wuhan Textile University, China

The classical fuzzy discriminant analysis with kernel methods (KFDA) is an effective method of solving nonlinearity pattern analysis problem. In some complicated cases, the kernel machine constituted by a single kernel function is not able to meet some practical application requirements, such as heterogeneous information or unnormalised data, non-flat distribution of samples, etc. By searching for an appropriate linear combination of base kernel functions or matrices, multiple kernel learning (MKL) is able to improve the performance in some extent. So it is a necessary choice to introduce multiple

The Theory of Type-2 Fuzzy Sets and Systems-II

Monday, July 10, 2:00PM-4:00PM, Room: Partenope, Chair: Robert John and Josie McCulloch

2:00PM The Non-Singleton Fuzzification Operation for General Forms of Interval Type-2 Fuzzy Logic Systems [#61]

Gonzalo Ruiz, Hani Hagra, Hector Pomares and Ignacio Rojas, Department of Computer Architecture and Computer Technology, Universidad de Granada, Spain; The Computational Intelligence Centre, School of Computer Science and Electronic Engineering University of Essex, United Kingdom

Recently, the theory regarding interval type-2 fuzzy sets and fuzzy logic systems has been further developed. In the first instance, the concepts of interval type-2 fuzzy sets were broadened, proving that this class of sets include some which are different from interval-valued sets. In a later work, the set theoretic operations of union and intersection on these sets were studied and presented under the framework of general type-2 fuzzy sets. This stimulated and motivated the further study of fuzzy logic systems using these new sets, which have been referred to as the general forms of interval type-2 fuzzy sets. However, as usual when a new fuzzy logic framework is presented, only the singleton version of these systems was introduced. In this work we aim to generalise that work, introducing the non-singleton general forms of interval type-2 fuzzy logic systems. We will present a real example on how to use these non-singleton fuzzy logic systems in real world applications.

2:15PM It Is Possible to Determine Exact Fuzzy Values Based on an Ordering of Interval-Valued or Set-Valued Fuzzy Degrees [#256]

Gerardo Muela, Olga Kosheleva, Vladik Kreinovich and Christian Servin, University of Texas at El Paso, United States; El Paso Community College, United States

In the usual $[0,1]$ -based fuzzy logic, the actual numerical value of a fuzzy degree can be different depending on a scale, what is important -- and scale-independent -- is the order between different values. To make a

kernel learning into KFDA in order to get better results. In this study, multiple kernel fuzzy discriminant analysis (MKFDA) is proposed. Our method obtains the projection matrix from fuzzy discriminant analysis with multiple kernel, and then feature extraction and classification are made based on the projection matrix. The experiment on the AVIRIS image was performed, and the results showed that the performance of fuzzy discriminant analysis with multiple kernels is better than that of fuzzy discriminant with single kernel for the Hyperspectral images' feature extraction and classification.

3:00PM Cross product kernels for fuzzy set similarity [#122]

Jorge Guevara, Roberto Hirata Jr and Stephane Canu, IBM Research, Brazil; University of Sao Paulo, Brazil; University of Normandy, France

We present a new kernel on fuzzy sets: the Cross Product kernel on fuzzy sets. This kernel implements a similarity measure between fuzzy sets with a geometrical interpretation in Reproducing Kernel Hilbert Spaces. We prove that this kernel is a convolution kernel that generalizes the widely known kernel on sets towards the space of fuzzy sets. Moreover, we show that the Cross Product kernel on fuzzy sets performs an embedding of probability measures into a Reproduction Kernel Hilbert space. Finally, we validated the kernel performance through experiments on supervised classification on noisy datasets.

description of fuzziness more adequate, it is reasonable to consider interval-valued degrees instead of numerical ones. Here also, what is most important is the order between the degrees. If we have only order between the intervals, can we, based on this order, reconstruct the original numerical values -- i.e., the degenerate intervals? In this paper, we show that such a reconstruction is indeed possible, moreover, that it is possible under three different definitions of order between numerical values.

2:30PM Type-1 and Interval Type-2 ANFIS: A Comparison [#258]

Chao Chen, Robert John, Jamie Twycross and Jonathan Garibaldi, University of Nottingham, United Kingdom

In a previous paper, we proposed an extended ANFIS architecture and showed that interval type-2 ANFIS produced larger errors than type-1 ANFIS on the well-known IRIS classification problem. In this paper, more experiments on both synthetic and real-world data are conducted to further investigate and compare the performance of interval type-2 ANFIS and type-1 ANFIS. For each dataset, interval type-2 ANFIS is optimised in three different ways, including a strategy suggested by Mendel such that interval type-2 ANFIS would be no worse than type-1 ANFIS. Our results show that in some circumstances the performance of interval type-2 ANFIS can be improved when it is initialised with blurred optimised type-1 ANFIS parameters. However, in general, interval type-2 ANFIS does not produce a clear performance improvement compared to type-1 ANFIS, especially on Mackey-Glass data with large noise. Thus, we conclude that the choice of interval type-2 ANFIS over type-1 ANFIS should be carefully considered, since type-2 ANFIS is more computationally complex, yet significantly better performance cannot be easily obtained.

2:45PM Evolutionary Multi-Objective based Hierarchical Interval Type-2 Beta Fuzzy System for classification problems [#363]

Yosra Jarraya, Souhir Bouaziz and Adel M. Alimi, National Engineering School of Sfax, Tunisia

This study addresses evolutionary structure optimization and parameter tuning processes for evolving a proposed Hierarchical interval Type-2 Beta Fuzzy System (HT2BFS). The structure learning phase is performed in a

multi-objective context by applying the Multi-Objective Extended Genetic Programming (MOEGP) algorithm. This phase aims to obtain a near-optimal structure of HT2BFS taking into account the optimization of two objectives, which are the accuracy maximization and the number of rules minimization. Moreover, a second parameter tuning phase is also performed in order to refine the parameters of the obtained near-optimal structure by applying the PSO-based Update Memory for Improved Harmony Search (PSOUM-IHS) algorithm. The system's performance is validated through two classification problems. Results prove the efficiency of the proposed approach.

3:00PM *A Novel Complexity Reduced Levenberge-Marquardt Optimization Algorithm: Application to the Training of Interval Type-2 Fuzzy Systems* [#565]

Mojtaba Ahmadi khansar and Erdal Kayacan,
Semnan University, Iran; Nanyang Technological
University, Singapore

Levenberge-Marquardt (LM) algorithm is a well-known optimization technique which has the advantages of the steepest descent and the Gauss-Newton

methods. Unfortunately, LM algorithm-based parameter update rules, regardless of being used to tune the parameters of artificial neural networks or neuro-fuzzy systems, require the calculation of inversion of high dimensional matrices. Matrix inversions are generally computationally expensive, and it is not desired in a real-time application where the computation speed is critical. In this paper, using matrix inversion lemma, LM algorithm is modified to avoid matrix inversion calculations, and therefore lessen its computational burden. The proposed algorithm is compared with the conventional LM algorithm for the training of interval type-2 fuzzy logic systems in terms of its speed. Extensive simulation results demonstrate that that the proposed novel method can increase the speed of LM algorithm by 50% while remaining the same performance.

Monday, July 10, 4:30PM-6:30PM

Adaptive fuzzy control for nonlinear systems

Monday, July 10, 4:30PM-6:30PM, Room: Normanna, Chair: Tsung-Chih Lin

4:30PM *Integration of Fuzzy CMAC and BELC Networks for Uncertain Nonlinear System Control* [#57]

Dajun Zhou, Fei Chao, Chih-Min Lin, Longzhi Yang and Changle Zhou, Xiamen University, China; Yuan Ze University, Taiwan; Northumbria University, United Kingdom

This paper develops a fuzzy adaptive control system consisting of a new type of fuzzy neural network and a robust controller for uncertain nonlinear systems. The new designed neural network contains the key mechanisms of a typical fuzzy CMAC network and a brain emotional learning controller network. First, the input values of the new network are delivered to a receptive field structure that is inspired from the fuzzy CMAC. Then, the values are divided into a sensory and an emotional channels; and the two channels interact with each other to generate the final outputs of the proposed network. The parameters of the proposed network are on-line tuned by the brain emotional learning rules; in addition, stability analysis theory is used to guarantee the proposed controller's convergence. In the experimentation, a "Duffing-Holmes" chaotic system and a simulated mobile robot are applied to verify the effectiveness and feasibility of the proposed control system. By comparing with the performances of other neural network based control systems, we believe our proposed network is capable of producing better control performances of complex uncertain nonlinear systems control.

4:45PM *A Controller for a Class of T-S Fuzzy Models with Uncertainty using Nussbaum-type Function* [#202]

Hugang Han, Prefectural University of Hiroshima, Japan

While the T-S fuzzy model is widely used as a model to design a controller for a system to be controlled, there is a gap, which is referred to as uncertainty, between the T-S fuzzy model and the system. The uncertainty is considered in this paper in an effort to improve the control system performance. Though the basic idea to tackle the uncertainty is to employ a frequently used fuzzy approximator approach, the relevant parameters are tuned by novel adaptive laws with the help of the Nussbaum-type function. Consequently, the closed-loop control system is able to be asymptotically stable.

5:00PM *A sufficient condition to guarantee the existence of fuzzy stable models on residuated logic programming with constraints* [#569]

Nicolas Madrid, University of Malaga, Spain

In this work we present a sufficient condition to guarantee the existence of stable models of residuated logic programs with constrain. Such condition is based on another result already published in the literature that guarantees the existence of stable models independently of the syntax. Specifically, it states that if the set of truth values is the unit interval $[0,1]$ and the connectives continuous, then every logic program without constraints has stable models.

5:15PM *A novel inequality approach to stability analysis of interval delayed T-S fuzzy systems* [#31]

An Jiyao, Chen Qingying and Xiao Bailong, Hunan University, China

This paper is considered with the stability problem of Takagi-Sugeno (T-S) fuzzy systems with interval time-varying delay. The delay is assumed to be differential with interval bounds, in which the delay derivative is also bounded in an interval. By utilizing some delay-dependent integral inequalities, a stability criterion is derived by employing the convex optimization method, which is addressed in terms of LMI. The result has advantage over existing ones since the upper bound of the derivative in quadratic terms are fully estimated and can work when upper bound of delay derivative is greater than one. Finally, an example is given to show the effectiveness of the proposed approach.

5:30PM *State Estimation and Stabilization of Continuous-Time Takagi-Sugeno Fuzzy Systems with Constraints of Positiveness and Superstability* [#89]

Yuri Talagaev, Balashov Institute of National Research Saratov State University, Russia

The paper deals with the new specific class of continuous-time T-S fuzzy systems, subject to conditions of positiveness and superstability simultaneously. The peculiarities of the behavior of the fuzzy system with and without bounded external disturbances are studied. Two mutually complementary approaches to the solution of the problem of positive

superstabilization of T-S fuzzy systems, reduced to the solution of the LP problems are revealed. The paper contains examples, demonstrating the ways of studying the conditions of existence and finding the fuzzy regulator, ensuring required behavior of the closed-loop T-S fuzzy system.

Ambient Computational Intelligence

Monday, July 10, 4:30PM-6:30PM, Room: Sveva, Chair: Ahmad Lotfi and Faiyaz Doctor

4:30PM *Predicting Activity Occurrence Time in Smart Homes with Evolving Fuzzy Models* [#544]

Rashmi Dutta Baruah, Manish Singh, Diganta Baruah and Iti Saha Misra, Indian Institute Of Technology Guwahati, India; Indian Institute of Technology Guwahati, India; Sikkim Manipal Institute of Technology, India; Jadavpur University, India

In this paper, we address the problem of predicting the time of occurrence of next activity, given the current activity and the context. The models that predict activity and time of occurrence rely on the basic idea that human beings perform sequence of activities at specific times regularly. In other words, the models are dependent on human behavior. However, human behavior changes over time. Also, due to demands and goals to be attained, there may be change in human behavior. Therefore, one of the essential requirements of the predictive models for the given task is autonomous adaptation with time and without undergoing any retraining. Considering the requirement of an adaptive model, we propose an evolving fuzzy rule-based predictive model that can autonomously adapt with changes in the human behavior. The model performance is evaluated using real-life data and satisfactory results are obtained.

4:45PM *Uncertainty Measures in an Ambient Intelligence Environment* [#606]

Caroline Langensiepen and Ahmad Lotfi, Nottingham Trent University, United Kingdom

In this paper we apply the Fuzzy Entropy and Approximate Entropy measures to the Activities of Daily Living (ADL) for a set of elderly subjects in their own homes, and compare the entropy measures against a simpler count of activity transitions. The aim is to assess whether a single relatively simple measure can give an overview of the ADL in order to provide summaries of the well-being of an elderly person for their carers or relatives. We find that both the entropy measures and activity count vary considerably between different elderly people, and from day to day. The absolute level of these measures seems to be indicative of different ADL levels. However, it appears that further analysis over a longer period and with more annotation by the volunteers is necessary before the measures can be appropriately interpreted.

5:00PM *An RBF Neural Network-based System for Home Smart Metering* [#424]

Antonino Staiano and Fabio Inneguale, University of Naples Parthenope, Italy; Nexera S.p.A., Italy

In the era of the Internet of Things (IoT), numerous application domains are emerging for a new generation of networked smart devices capable to process and communicate data over the Internet, for building a new smart world. While some large scale domains are certainly of a special interest, e.g., smart grid, some others small scale applications, e.g., smart home, give any user the chance to build his own IoT system. Thanks to the technological

development, it is now possible to use and integrate cheap technologies to monitor the state of our homes. The paper is devoted to the implementation of an inexpensive system to measure the energy consumption of a home electrical appliances. An Arduino board equipped with a proper sensor is connected to the specific appliance one wants to monitor, and a web application running on a web server accessible through any device, i.e., pc, tablet or smartphone, makes it possible the real-time monitoring of the energy consumptions and to query for the historical energy rates. Moreover, a forecasting module based on a Radial Basis Function Neural Network trained, in the first layer, by a rough-fuzzy supervised clustering, provides future energy trends.

5:15PM *Analyzing Social Networks Activities to Deploy Entertainment Services in HRI-based Smart Environments* [#609]

Pasquale D'Alterio, Giovanni Acampora and Silvia Rossi, University of Naples Federico II, Italy

Smart home systems have become increasingly widespread in the last few years. State-of-the-art smart home architectures concentrate on modeling the user physical behavior and on discovering possible behavioral pattern, while they provide very little personalization of the services based on the individual cognitive characteristics. In this direction, the analysis of the user activity on social networks offers a reliable and efficient way to obtain psychological traits of a human being in a manner that can be easily integrated with smart systems. In this paper, we outline a robot based architecture that blends ubiquitous computing and personality analysis to provide a custom-tailored system. An entertainment recommender scenario with a social robot is then analyzed as a case study.

5:30PM *Fuzzy Inference Classifier for Road Anomalies Identification* [#215]

Sanchez Fernandez Luis Pastor, Ramirez-Venegas Carlos Alberto, Carbajal Hernandez Jose Juan and Sanchez Perez Luis Alejandro, Instituto Politecnico Nacional, Centro de Investigacion en Computacion, Mexico

Road network quality condition should be monitored continuously. Several efforts for developing new technologies that automatically detect and recognize road events have been made, contributing improvement, traveling efficiency and good quality road state by implementing immediate corrective actions. In this work, a new model for identifying road events has been developed, classifying them in different road anomalies (potholes, cracks and planned events in bad condition) and events that are considered as part of the road (speed bumps, patches). This work presents a fuzzy classifier for recognizing this type of events using a set of fuzzy rules designed to identify each event through a statistical analysis and navigational data extracted from real environments. So that, the fuzzy model presents a good performance based on a parallel data processing with lower execution time than sequential algorithms present in the literature.

Applications of Fuzzy Systems in Modeling, Identification, and Control of Aerospace Vehicles

Monday, July 10, 4:30PM-6:30PM, Room: Santa Lucia, Chair: Mohammad Ayoubi and Kelly Cohen

4:30PM *LMI-Based Fuzzy Optimal Variance Control of Airfoil Model Subject to Input Constraints* [#134]
Sean S. M. Swei and Mohammad A. Ayoubi, NASA Ames Research Center, United States; Santa Clara University, United States

This paper presents a study of fuzzy optimal variance control problem for dynamical systems subject to actuator amplitude and rate constraints. Using Takagi-Sugeno fuzzy modeling and dynamic Parallel Distributed Compensation technique, the stability and the constraints can be cast as a multi-objective optimization problem in the form of Linear Matrix Inequalities. By utilizing the formulations and solutions for the input and output variance constraint problems, we develop a fuzzy full state feedback controller. The stability and performance of the proposed controller are demonstrated through its application to the airfoil flutter suppression.

4:45PM *Multi-Source Sensor Fusion for Small Unmanned Aircraft Systems Using Fuzzy Logic* [#317]
Brandon Cook and Kelly Cohen, NASA Ames Research Center, United States; University of Cincinnati, United States

As the applications for using small Unmanned Aircraft Systems (sUAS) beyond visual line of sight (BVLOS) continue to grow in the coming years, it is imperative that intelligent sensor fusion techniques be explored. In BVLOS scenarios the vehicle position must accurately be tracked over time to ensure no two vehicles collide with one another, no vehicle crashes into surrounding structures, and to identify off-nominal scenarios. In this study, an intelligent systems approach is used to estimate the position of sUAS given a variety of sensor platforms, including GPS, radar, and onboard detection hardware.

Fuzzy Logic in Service Operations

Monday, July 10, 4:30PM-6:30PM, Room: Aragonese, Chair: Andrew Starkey and Gilbert Owusu

4:30PM *Fuzzy Dominance Rules for Real-World Many Objective Optimization* [#123]
Andrew Starkey, Hagrah Hani, Shakya Sid and Owusu Gilbert, University of Essex, United Kingdom; EBTIC, United Arab Emirates; British Telecom, United Kingdom

In real world optimization problems there are often multiple objectives to consider. However, with traditional multiobjective optimization algorithms, like the Non-Dominated Sorting Genetic Algorithm, NSGA-II, one solution is not produced at the end of the process but a set of non-dominated solutions. This set of solutions make up what is known as the Pareto front. The Pareto front relies on calculating the dominance of each solution the multi-objective algorithm produces. Traditional dominance calculations are reasonable for a small number of objectives. However, the more objectives there are in the problem, the more unsuitable these dominance calculations become. This leads to poor selection criteria and ultimately a weaker form of optimization when compared to a small number of objectives. In this paper, we present a fuzzy logic system for computing dominance between two solutions. We have evaluated this fuzzy logic system in optimizing a set of black box test problems. In addition, we have also applied it to a real world many-objective system that optimizes five conflicting objectives, in the telecommunications domain. The implementation of the fuzzy logic system has led to the NSGA-II algorithm with Fuzzy Dominance Rules (FDRs) being able to perform better in a number of black box tests and improving the results of our real-world many-objective optimization problem, with a statistically significant improvement to the hypervolume of 5.46%.

Common research challenges include multiple sensor platforms and sensor reliability. In an effort to resolve these challenges, techniques such as a Maximum a Posteriori estimation and Fuzzy Logic based sensor confidence determination are used.

5:00PM *Transformation of a Hierarchical Mamdani Fuzzy System to a Single Fuzzy System Representation* [#323]

Timothy Arnett, Kelly Cohen, Matthew Clark, David Casbeer and Kuldip Rattan, University of Cincinnati, United States; Air Force Research Laboratory, WPAFB, United States; Wright State University, United States

As of late, hierarchical Fuzzy Inference Systems (hFIS) have received considerable attention because of their ability to control complex decision-making procedures. Although the performance of hFISs appears to be extremely effective in complex scenarios, there is a question about the differences between the hierarchical and single FISs (sFIS) and the relationship between the two. In this work, a transformation is derived which converts a Mamdani type hFIS into its equivalent sFIS representation. This is accomplished by equating their output membership functions. The equivalency between the outputs of the two representations is proven using a Satisfiability Modulo Theories (SMT) solver approach. Furthermore, we provide a detailed development procedure and results are presented which demonstrate the ease of implementation of the transformation as well as a wide applicability to meaningful large-scale problems.

4:45PM *Intelligent Real-Time Scheduling of Dynamic Processes in MPI* [#471]
Ahmed Moussa, Sherif Embaby and Ibrahim Farag, Cairo University, Egypt

The Message Passing Interface (MPI), which appeared in 1994, introduced many powerful functionalities for parallel processing positioning the MPI among the top preferred packages for parallel processing for researchers and developers. However, MPI-1 did not provide mechanisms for creating runtime processes. Although MPI-2 included spawn process creation, it did not specify how those dynamically created processes may be assigned to hardware processors. This resulted in poor resource allocation, load balancing, and consequently bad performance too. In this paper, the researchers discuss this problem proposing a fuzzy scheduling algorithm for dynamic processes, which proved to vastly outperform the native MPI scheduler.

5:00PM *Fuzzy Decision Tree and Fuzzy Gradual Decision Tree: Application to Job Satisfaction* [#568]
Christophe Marsala and Maria Rifqi, Universite Pierre et Marie Curie (UPMC), France; Universite Pantheon-Assas - Paris 2, France

In this paper, a comparison of the behaviour of fuzzy decision trees and gradual fuzzy decision trees is presented in a real-world application in the context of labour economics. The aim of this study is on one hand to present, in a real case, the good property of interpretability of such decision trees. On the other hand, it shows the importance to take into account a graduality relation between attributes and the class during the construction of a fuzzy decision tree. The obtained results illustrate the differences between the two types of fuzzy decision trees.

5:15PM *ELECTRE Method Using Interval-Valued Intuitionistic Fuzzy Sets and Possibility Theory for Multi-Criteria Decision Making Problem Resolution* [#55]

Fatma Dammak, Leila Baccour, Abdelkarim Ben ayed and Adel M. Alimi, ENIS, Tunisia

In this work we propose an approach of multicriteria decision making (MCDM) using Elimination Et Choice Transiting Reality (ELECTRE) methods, interval-valued intuitionistic fuzzy (IVIF) sets and possibility theory. The proposition concerns the computation of concordance sets and discordance sets using possibility measures. The proposed approach is applied to select the best investment projects decision problem from literature. Therefore results are compared and concluding remarks are given.

5:30PM *Fuzzy Decision Support Systems in Marine Practice* [#138]

Marina Solesvik, Yuriy Kondratenko, Galyna Kondratenko, Ievgen Sidenko, Vyacheslav Kharchenko and Artem Boyarchuk, Nord University, Norway; Petro Mohyla Black Sea National University, Ukraine; National Aerospace University-KhAI, Ukraine

The article is a review of the perspective methods and approaches to the design of fuzzy decision support systems (DSS) with the application of discrete fuzzy inference engine. The authors also developed a two-stage method for fuzzy rule base (RB) correction in the case of changing the structure of the input vector. In addition, the fuzzy DSS with a hierarchical

Theoretical aspects of aggregation functions II

Monday, July 10, 4:30PM-6:30PM, Room: Catalana, Chair: Radko Mesiar, Javier Montero, Javier Fernández Humberto Bustince

4:30PM *On some New Relations Between Copulas and Fuzzy Implication Functions* [#80]

Sebastia Massanet, Daniel Ruiz-Aguilera and Joan Torrens, University of the Balearic Islands, Spain

Copulas are a special kind of aggregation functions that have been deeply investigated because of their applications in many fields, specially in Statistics and Economy. An important research topic from the theoretical point of view is the study of new construction methods of copulas. In this line, this paper presents two construction methods based on probabilistic implications and survival implications. From these construction methods, the axiomatic characterization of these families of fuzzy implication functions, which are in fact the same, is presented.

4:45PM *F-transforms, Aggregations, Partitions* [#356]

Irina Perfilieva, IRAFM, Czech Republic

A relationship between real-valued and lattice-valued F-transforms and aggregation functions is analyzed. For each direct F-transform, we find an axiomatic characterization of the corresponding mapping. We show that the real-valued F-transform is a set of images of linear aggregation functions and that the lattice-valued F-transforms are images of linear-like maps. In all cases, the involved maps respect certain partitions of the universe.

5:00PM *Comparing Families of measures of k-Specificity. Measure of Crispness.* [#208]

Jose Luis Gonzalez Sanchez, Ramon Gonzalez Del Campo, Luis Garmendia and Ronald Yager, Complutense University of Madrid, Spain; Iona College, United States

Measures of k-specificity are generalizations of Yager's measures of specificity of fuzzy sets or possibility distribution to measure the tranquility

structure for the best selection of the marine delivery company was developed. Simulation results confirm the effectiveness and feasibility of fuzzy DSS structure with variable input coordinates vector, in particular, in marine practice.

5:45PM *Logistic Informatics Modelling Using Concept of Stratification (CST)* [#194]

Mehdi Rajabi Asadabadi, Saberi Morteza and Elizabeth Chang, School of Business, The University of New South Wales, Canberra, Australia, Australia

The concept of stratification (CST) is a reform in problem solving approaches in computer science introduced and developed by Lotfi Zadeh [1]. In this innovative approach, the target set is the initial states. The environment around the target is then systematically identified and stratum around the target are gradually built using the concept of 'incremental target enlargement'. We advocate that this approach is useful in different areas; however, it is essential to highlight the potential applicability of the approach by presenting different examples. In this paper illustrative examples in Information Dominance (ID) and in requirement elicitation in contracting, are structured using CST. These examples illustrate the application of the concept in the contexts of logistic informatics and contracting and assists the modelling process. Of particular relevance are Example 4 and 5. Example 4 exposes situations that are not dealt with in the current form of CST. The study, therefore, extends CST by considering the possibility of occasional state repetition while using the same input. Further, a 3D version of CST is structured and proposed for future applications. This proposed version of the concept illustrates how the Fuzzy Inference System (FIS) benefits the user when applying CST.

when choosing one element, extended to choose k elements from the universe of discourse. In this paper a new measure of k-specificity is defined, a definition of measures of crispness is provided, and an example of measure of crispness is given.

5:15PM *(T,N)-Implications* [#277]

Jocivania Pinheiro, Benjamin Bedregal, Regivan Santiago and Helida Santos, Rural Federal University of Semiárid (UFERSA), Brazil; Federal University of Rio Grande do Norte (UFRN), Brazil

The aim of this work is to study a fuzzy implication called (T,N)-implication, obtained by the composition of a fuzzy negation and a t-norm. It discusses under which conditions such functions preserve the main properties of fuzzy implications, in which some are related to the laws of contraposition. Finally, we prove a result that ensure the necessary and sufficient conditions for a function $I : [0; 1]^2 \rightarrow [0; 1]$ to be a (T,N)-implication.

5:30PM *Using E-operators to Extend Lattice-valued Uninorms and Nullnorms* [#386]

Eduardo S. Palmeira and Benjamin Bedregal, Universidade Estadual de Santa Cruz, Brazil; Universidade Federal do Rio Grande do Norte, Brazil

In this paper we apply an extension method via e-operator to extend lattice-valued uninorms and nullnorms from a sublattice to a greater one, in order to verify which algebraic properties of them are preserved by the extension method.

5:45PM *Hesitant Fuzzy Sets and Relations using Lists* [#207]

Ramon Gonzalez Del Campo, Luis Garmendia, Jordi Recasens and Javier Montero, Complutense University of Madrid, Spain; Technical University of Barcelona, Spain

Hesitant Fuzzy Sets are useful to represent the information given by several experts. However, this possibility usually require to deal with sets of values with different cardinality and the necessity to compare them, it is, not all experts evaluate all the elements in the universe. In this paper it is proposed a new nomenclature for Hesitant Fuzzy Sets called Hesitant Fuzzy Sets using Lists. It is proposed a new partial order relation between lists of membership degrees. This partial order relation allows to handle lists with different lengths. In addition, Hesitant Fuzzy Relations on Lists operations are defined and the T-transitive closure of a Hesitant Fuzzy Relation is given. It is proved this T-transitive closure always exists and it is unique. Finally, an

algorithm to compute the T-transitive closure of a Hesitant Fuzzy Relation is proposed and several examples are given.

6:00PM *New Types of Ordinal Sum of Fuzzy Implications* [#501]

Michal Baczynski, Pawel Drygas, Anna Krol and Radko Mesiar, University of Silesia, Institute of Mathematics, Poland; University of Rzeszow, Faculty of Mathematics and Natural Sciences, Poland; Slovak University of Technology, Faculty of Civil Engineering, Slovakia

In this contribution new ways of constructing of ordinal sum of fuzzy implications are proposed. These methods are based on a construction of ordinal sums of overlap functions. Moreover, preservation of some properties of these ordinal sums of fuzzy implications are examined. Among others neutrality property, identity property, and ordering property are considered.

DM III: Group Decision Making and Consensus

Monday, July 10, 4:30PM-6:30PM, Room: Giardino, Chair: Javier Cabrerizo Francisco Chiclana

4:30PM *An Alternative-Consensus Optimization Model with Crisp and Interval Opinions* [#187]

Zaiwu Gong, Zhao Wei, Gao Ge, Cai Mei and Wang Lihong, Information Science and Technology, China; National Climate Center, China

We construct two types of alternative-consensus optimization models that concern crisp numbers and intervals for the DMs' opinions. In the alternative-consensus (interval) data envelopment analysis (DEA) model, the optimal alternative is the decision-making unit with the highest output utility, which is also the maximum consensus alternative. The alternative-consensus (interval) optimization model based on the maximum discriminating factor obtains the fixed weights of the DMs on different alternatives. Its essence is to increase the differences in weights among the DMs and improve the differences in the overall output utilities among alternatives by maximizing the discriminating factor, which overcomes the drawback that the optimal alternative is not unique in the alternative-consensus (interval) DEA model.

4:45PM *On minimum cost consensus model considering individual tolerance levels* [#235]

Wu Zhibin and Yang Xieyu, Sichuan University, China

The consensus process plays a decisive role in a group decision making problem. From a perspective of optimization, various consensus models have been presented to help the group reach a predefined consensus level. The aim of this paper is to propose a new primal model and its dual model based on the minimum cost consensus model. In the proposed primal model, different tolerance levels are considered for the decision makers and the group opinion is obtained by the weighted arithmetic average operators. In such a model, the moderator does not need to pay if the changed opinion of a decision maker is still under the tolerance level of that decision maker. The proposed dual consensus model has some significant economic interpretations. Some properties with respect to the two proposed consensus models are analyzed. The validity of the proposed models is illustrated by a numerical example.

5:00PM *Expanded Hesitant Fuzzy Sets and Group Decision Making* [#598]

Jose Carlos R. Alcantud and Gustavo Santos-Garcia, University of Salamanca, Spain

We define expanded hesitant fuzzy sets, which incorporate all available information of the decision makers that provide the membership degrees that define a hesitant fuzzy set. We show how this notion relates to hesitant fuzzy set and extended hesitant fuzzy set. We define various scores for this setting, which generalize popular scores for hesitant fuzzy elements. Finally, a group decision making procedure is presented and illustrated with an example.

5:15PM *Dealing with Diversity and Novelty in Group Recommendations using Hesitant Fuzzy Sets* [#158]

Jorge Castro, Manuel J. Barranco, Rosa M. Rodriguez and Luis Martinez, University of Granada, Spain; University of Jaen, Spain

Diversity and novelty are appreciated features by users of recommender systems, which alleviate the information overload problem. These features are more important in recommendation to groups because members interests and needs differ from each other or are even in conflict. Various techniques have been used to recommend to groups. However, these techniques apply an aggregation step that imply a loss of information, which negatively affect the recommendation. We aim at avoiding the negative influence of the aggregation step considering the various interests and needs of the group members as the group hesitation, thus, our proposal uses Hesitant Fuzzy Sets to model the group information. A case study is performed to evaluate the proposal, whose results show its performance regarding recommendation diversity, novelty and accuracy.

5:30PM *An optimization-based approach with minimum preference loss to fuse incomplete linguistic distributions in group decision making* [#33]

Yuzhu Wu and Yucheng Dong, Sichuan University, China

The linguistic distribution is becoming a popular tool to model linguistic expressions in group decision making. Due to the knowledge limitation, it is difficult for decision makers to provide complete linguistic distribution information and partial ignorance exists in practical group decision making problems. Meanwhile, in group decision making it is hoped to find a group opinion whose distribution information is complete and the preference loss between this group opinion and individual opinions is the minimum. To tackle these issues, this paper introduces the concept of incomplete linguistic distributions and proposes a new model called the minimum preference loss model (MPLM), aiming at minimizing the preference loss between the group opinion and individual opinions in the group decision making with incomplete linguistic distributions. Finally, a numerical example is provided to demonstrate our model.

5:45PM *An Optimization Method to Estimate The Missing Elements for The Incomplete Fuzzy Reciprocal Preference Relation* [#69]

Yejun Xu and Qianqian Wang, Hohai University, China

In this paper, we investigate the missing elements estimation issue of incomplete fuzzy reciprocal preference relation. Based on the multiplicative consistency property, a constrained nonlinear optimization model (CNOM),

which aims for making the induced matrix close to zero, is proposed to estimate the missing elements in the incomplete fuzzy reciprocal preference relation. The numerical example is illustrated to show the correctness and effectiveness of the proposed method. Our method not only estimates the

missing elements accurately but also improves the multiplicative consistency, which makes the decision result derived from the incomplete fuzzy reciprocal preference relation could be scientific and effective.

Bio-inspired Fuzzy Logic Approaches – Interdisciplinary Emergent Technologies

Monday, July 10, 4:30PM-6:30PM, Room: Borbonica, Chair: Mario Pavone and Vladik Kreinovich

4:30PM *Gompertz Fuzzy Model for Plant Disease Evolution* [#42]

Narcis Clara and Xavier Bertran, University of Girona, Spain

Plant disease experimental data have been shown to fit better with a crisp Gompertz model rather than a logistic model. A fuzzy approach based on Zadeh's Extension Principle, which leads to four systems of two parameter dependent autonomous differential equations, is applied to this subject. The solution is monitored from the initial fuzzy conditions through to the three different domains and two sub-domains. While results show properties of the crisp Gompertz model being kept and then lost, this is still an appropriate generalized way to deal with uncertainty in plant disease evolution.

4:45PM *Fuzzy Logic for Dynamic Simultaneous Adaptation of Parameters in the Grey Wolf Optimizer* [#216]

Luis Rodriguez, Oscar Castillo, Jose Soria, Mario Garcia, Fevrier Valdez and Patricia Melin, Tijuana Institute of Technology, Mexico

The main goal of the work presented in the paper is to introduce the use of fuzzy logic in the Grey Wolf Optimizer (GWO) algorithm, specifically for dynamic simultaneous adaptation of the key parameters, which are determinant in the performance of the metaheuristic. The proposed approach for this modification of GWO using fuzzy logic is presented. In addition, a brief comparison between the traditional GWO algorithm and the Grey Wolf Optimizer using fuzzy logic for dynamic adaptation of parameters is reported. This research shows the individually dynamic adjustment of two parameters and a proposal of how to simultaneously adjust both parameters and finally we present the performance of these methods when they are tested with a set of benchmark functions, showing the advantage of using the simultaneous adaptation of parameters.

5:00PM *Iterative Fireworks Algorithm based on Fuzzy Dynamic Coefficients* [#217]

Juan Barraza, Patricia Melin, Fevrier Valdez, Claudia Gonzalez and Oscar Castillo, Tijuana Institute of Technology, Mexico

the main aim of this paper is to use fuzzy inference systems for controlling the relevant parameters within the equations of the FWA algorithm. In other words, parameters that are considered constant in the traditional FWA and are now made dynamic by using fuzzy logic. It is worth mentioning that we also made a modification to the algorithm with the goal of having a better performance and the modification was to change the stopping criteria of the algorithm. In the conventional fireworks algorithm (FWA) the stopping criteria is based on the function evaluations, including, some variations or modifications of the FWA they also manage in the same way. We propose stopping criteria based on the iterations with the goal of having a more precise control and consequently, and thus, power in better way to control the output variables in a Fuzzy Inference System (FIS) of Mamdani type, since the number of iterations is used as the input variable. To demonstrate the validity of this modification we tested the algorithm with 12 benchmark

functions with good results, and we call the proposed algorithm as Iterative Fuzzy Fireworks Algorithm and we denoted as IFFWA.

5:15PM *Facial emotion recognition using emotional neural network and hybrid of fuzzy c-means and genetic algorithm* [#314]

Ehsan Lotfi, Abbas Khosravi and Saeid Nahavandi, Azad University, Torbat-e Jam Branch, Iran; Deakin University, Australia

Facial emotion recognition (FER) is a critical task for both human-human (HHI) and human-computer interactions (HCI). In this paper, a brain-inspired neural basis computational model of FER is proposed based on emotional neural networks (ENN), fuzzy c-means (FCM) and genetic algorithms (GA). The proposed model can be applied in both HHI and HCI applications. In HHI, it can be used for improving communication skills, and in HCI it can be used in various treatment processes e.g. anxiety treatment, cancer radiation treatment and remote children/elderlies monitoring systems. The proposed model consists of main modules of emotional brain which recognize the facial emotions. In the experimental studies, the proposed model is examined on children's facial sad recognition as a case study. The results show that our model is valid and can be applied for various FER tasks.

5:30PM *New Model of Information Processing at Granule Cell Layer Makes Cerebellum as Biological Equivalent for ANFIS and CANFIS: Sharing of Processing Resources and Generalization* [#577]

Lavdim Kurtaj, Vjosa Shatri and Ilir Limani, University of Prishtina "Hasan Prishtina, Albania

Puzzling about cerebellum is its wide range of functional involvement with its seemingly uniform structure. Late views based on connectivity with other parts of the brain implicate it, from traditional lower level role in balance and coordination of movements, up to cognition and emotional level. Cerebellar models are used in attempts to explain this functional involvement, with possible benefits in solving similar technical problems. Information processing in the input layer used by these models can easily reach biological and practical limits in number of neurons required, even though cerebellum hosts more than half of total number of neurons in the brain, most of them in the input layer. To relax these limits for some representative tasks, new model of information processing at input layer, named granule cell layer, is used. This paper presents information processing at the basic granule cell-Golgi cell (GrC-GoC) building block of the first cerebellar processing layer, and overall cerebellar processing becoming similar to fuzzy models of Adaptive-Network-Based Fuzzy Inference System (ANFIS) and CoActive Neuro-Fuzzy Inference Systems (CANFIS) types. Simulink spiking model illustrates functionality of GrC-GoC block. It generates as a result multidimensional receptive fields from traditional group of mossy fibers with population code that drive GrC, which are gain modulated by other input of GoC driven by second group of mossy fibers with rate code. Simulink behavioral model of a cerebellum with new structure is used in two robotics applications. Model shows wider sharing of processing resources, and generalization capabilities that it offers, with more biologically plausible learning.

Fuzzy Systems for Big Data

Monday, July 10, 4:30PM-6:30PM, Room: Auditorium, Chair: Francisco Herrera Alberto Fernández

4:30PM *Chi-Spark-RS: an Spark-built Evolutionary Fuzzy Rule Selection Algorithm in Imbalanced Classification for Big Data Problems* [#213]

Alberto Fernandez, Eva Almansa and Francisco Herrera, University of Granada, Spain

The significance and benefits of addressing classification tasks in Big Data applications is beyond any doubt. To do so, learning algorithms must be scalable to cope with such a high volume of data. The most suitable option to reach this objective is by using a MapReduce programming scheme, in which algorithms are automatically executed in a distributed and fault tolerant way. Among different available tools that support this framework, Spark has emerged as a "de facto" solution when using iterative approaches. In this work, our goal is to design and implement an Evolutionary Fuzzy Rule Selection algorithm within a Spark environment. To do so, we build different local rule bases within each Map Task that are later optimized by means of a genetic process. With this procedure, we seek to minimize the total number of rules that are gathered by each Reduce task to obtain a compact and accurate Fuzzy Rule Based Classification System. In particular, we set the experimental framework in the scenario of imbalanced classification. Therefore, the final objective will be analyzing the best synergy between the novel Evolutionary Fuzzy Rule Selection algorithm and the solutions applied to cope with skewed class distributions, namely cost-sensitive learning, random under-sampling and random- oversampling.

4:45PM *A global distributed approach to the Chi et al. Fuzzy Rule-Based Classification System for Big Data classification problems* [#245]

Mikel Elkano, Mikel Galar, Jose Sanz, Gracaliz Dimuro and Humberto Bustince, Department of Automatics and Computation, Public University of Navarre, Spain; Centro de Ciencias Computacionais, Universidade Federal do Rio Grande, Brazil

The main drawback of Fuzzy Rule-Based Classification Systems (FRBCSs) when they are applied in Big Data problems is the lack of scalability. Previously proposed approaches consist in concurrently fitting several Chi et al. FRBCSs whose rule bases are then aggregated to obtain the final model. This methodology is seriously affected by the degree of parallelism used for the execution of the algorithm, showing a significant decrease in classification performance as the degree of parallelism increases. This work focuses on the design of a new FRBCS for Big Data classification problems (CHI-BD) that generates exactly the same rule base regardless of the degree of parallelism. Our approach recovers the model that would be built by the original Chi et al. algorithm if it was able to deal with Big Data problems.

5:00PM *Scalable Modeling of Thermal Dynamics in Buildings using Fuzzy Rules for Regression* [#458]

Rodriguez-Mier Pablo, Mucientes Manuel and Bugarin Alberto, University of Santiago de Compostela, Spain

The reduction of energy consumption in buildings is one of the goals to improve energy efficiency. One way to achieve energy savings in buildings is to develop intelligent control heating strategies that are able to reduce the power consumption by predicting the behavior of the thermal dynamics under different control schemes. One way to accomplish this is by means of learning fuzzy rules using the data collected from different sensors installed in buildings to generate regression models that are accurate and interpretable, so the generated models can be understood by the experts who approve the energy-saving schemes. However, one important issue is the generation of accurate knowledge bases of fuzzy rules for regression that can scale with the large amount of information generated by the many sensors installed in buildings, which will continue to grow in the coming years. For this purpose, in this paper we evaluate the scalability of two genetic fuzzy systems, FRULER and S-FRULER in the domain of thermal dynamics in buildings, using real data from a residential college at the USC.

5:15PM *Incremental Fuzzy Learning Algorithms in Big Data Problems: A Study on the Size of Learning Subsets* [#460]

Rocio Romero-Zaliz, Antonio Gonzalez and Raul Perez, University of Granada, Spain

Incremental approaches may be used to speed up the learning process when a classification algorithm is dealing with big data bases. In this work we present a study on how the size and composition of the set of learning examples that are given to an incremental algorithm affect its behaviour.

5:30PM *A first approach to handle fuzzy emerging patterns mining on big data problems: The EvAEFP-Spark algorithm* [#463]

A.M. Garcia-Vico, P. Gonzalez, M.J. del Jesus and C.J. Carmona, University of Jaen, Spain; University of Burgos, Spain

Internet and the new technologies are generating new scenarios with and a significant increase of data volumes. The treatment of this huge quantity of information is impossible with traditional methodologies and we need to design new approaches towards distributed paradigms such as MapReduce. This situation is widely known in the literature as Big Data. This contribution presents a first approach to handle fuzzy emerging patterns in big data environments. This new algorithm is called EvAFP-Spark and is development in Apache Spark based on MapReduce. The use of this paradigm allows us the analysis of huge datasets efficiently. The main idea of EvAEFP-Spark is to modify the methodology of evaluation of the populations in the evolutionary process. In this way, a population is evaluated in the different maps, obtained in the Map phase of the paradigm, and for each one a confusion matrix is obtained. Then, the Reduce function accumulates the confusion matrix for each map in a general matrix in order to evaluate the fitness of the individuals. An experimental study with high dimensional datasets is performed in order to show the advantages of this algorithm in emerging patterns mining.

5:45PM *Exact Fuzzy k-Nearest Neighbor Classification for Big Datasets* [#482]

Jesus Maillo, Julian Luengo, Salvador Garcia, Francisco Herrera and Isaac Triguero, Department of Computer Science and Artificial Intelligence, University of Granada, Spain; School of Computer Science, University of Nottingham, Jubilee Campus, England

The k-Nearest Neighbors (kNN) classifier is one of the most effective methods in supervised learning problems. It classifies unseen cases comparing their similarity with the training data. Nevertheless, it gives to each labeled sample the same importance to classify. There are several approaches to enhance its precision, with the Fuzzy k-Nearest Neighbors (Fuzzy-kNN) classifier being among the most successful ones. Fuzzy-kNN computes a fuzzy degree of membership of each instance to the classes of the problem. As a result, it generates smoother borders between classes. Apart from the existing kNN approach to handle big datasets, there is not a fuzzy variant to manage that volume of data. Nevertheless, calculating this class membership adds an extra computational cost becoming even less scalable to tackle large datasets because of memory needs and high runtime. In this work, we present an exact and distributed approach to run the Fuzzy-kNN classifier on big datasets based on Spark, which provides the same precision than the original algorithm. It presents two separately stages. The first stage transforms the training set adding the class membership degrees. The second stage classifies with the kNN algorithm the test set using the class membership computed previously. In our experiments, we study the scaling-up capabilities of the proposed approach with datasets up to 11 million instances, showing promising results.

6:00PM *A Scalable Evolutionary Linguistic Fuzzy System with Adaptive Defuzzification in Big Data* [#589]

Antonio Angel Marquez, Francisco Alfredo Marquez and Antonio Peregrin, University of Huelva, Spain

This work deals with the design of scalable methodologies to build the Rule Bases of Linguistic Fuzzy Rule Based Systems from examples for Fuzzy Regression in Big Data environments. We propose a distributed MapReduce model based on the use of an adaptation of a classic data driven method followed by an Evolutionary Adaptive Defuzzification to increase the accuracy of the final fuzzy model.

Type-1 and type-2 neuro fuzzy systems: quo vadis?

Monday, July 10, 4:30PM-6:30PM, Room: Partenope, Chair: Erdal KAYACAN

4:30PM *Interval Type-2 Fuzzy-Neuro Control of Nonlinear Systems With Proved Overall System Stability* [#173]

Chao Zhang, Claudio Rossi and Erdal Kayacan, Nanyang Technological University, Singapore; Universidad Politecnica de Madrid, Spain

In this paper, we put forward an interval type-2 fuzzy neural network (IT2FNN) to deal with control issues of nonlinear systems with uncertainties. The fuzzy rules of the IT2FNN use interval type-2 triangular fuzzy sets to account for antecedent parts and adopt crisp numbers for the corresponding consequents. To effectively cope with uncertainties in the systems, a sliding-mode-control theory-based approach with new parameter learning rules is proposed to update the IT2FNN. The overall stability of the proposed methodology is also proved by using appropriate Lyapunov functions. Finally, the proposed method is applied to control the angular position of an inverted pendulum system. Simulation results indicate that, compared to a conventional proportional-derivative controller, the IT2FNN with the proposed learning rules can eliminate the uncertainties in performance and efficiently track the angle trajectory as desired.

ZNFN based control system is compared with the performance of the other controllers. The obtained results demonstrate the suitability of using of designed system in control of dynamic plants

5:15PM *Distributed On-line Learning for Random-Weight Fuzzy Neural Networks* [#543]

Roberto Fierimonte, Rosa Altilio and Massimo Panella, DIET - University of Rome "La Sapienza", Italy

The Random-Weight Fuzzy Neural Network is an inference system where the fuzzy rule parameters of antecedents (i.e., membership functions) are randomly generated and the ones of consequents are estimated using a Regularized Least Squares algorithm. In this regard, we propose an on-line learning algorithm under the hypothesis of training data distributed across a network of interconnected agents. In particular, we assume that each agent in the network receives a stream of data as a sequence of mini-batches. When receiving a new chunk of data, each agent updates its estimate of the consequent parameters and, periodically, all agents agree on a common model through the Distributed Average Consensus protocol. The learning algorithm is faster than a solution based on a centralized training set and it does not rely on any coordination authority. The experimental results on well-known datasets validate our proposal.

4:45PM *Hybrid Multi-objective Forecasting of Solar Photovoltaic Output Using Kalman Filter based Interval Type-2 Fuzzy Logic System* [#558]

Saima Hassan, Mojtaba Ahmadi Khanesar, Amin Hajizadeh and Abbas Khosravi, Kohat University of Science and Technology, Kohat, Pakistan, Pakistan; Semnan University, Iran; Aalborg Universitet Esbjerg, Denmark; Centre for Intelligent Systems Research, Deakin University, Australia

Learning of fuzzy parameters for system modeling using evolutionary algorithms is an interesting topic. In this paper, two optimal design and tuning of Interval type-2 fuzzy logic system are proposed using hybrid learning algorithms. The consequent parameters of the interval type-2 fuzzy logic system in both the hybrid algorithms are tuned using Kalman filter. Whereas the antecedent parameters of the system in the first hybrid algorithm is optimized using the multi-objective particle swarm optimization (MOPSO) and using the multi-objective evolutionary algorithm Based on Decomposition (MOEA/D) in the second hybrid algorithm. Root mean square error and maximum absolute error as the two accuracy objective are utilized to find the Pareto-optimal solution with the MOPSO and MOEA/D respectively. The proposed hybrid multi-objective designs of the interval type-2 fuzzy logic system are utilized to the prediction of solar photovoltaic output. It is observed that MOEA/D outperforms MOPSO in this case in terms of quality of results and its diversity. Finally, one point is selected from the obtained Pareto front and its performance is illustrated.

5:30PM *Electricity Price Forecasting using Asymmetric Fuzzy Neural Network Systems* [#88]

Abeer Alshejari and Vassilis Kotsogiannis, University of Westminster, United Kingdom

Electricity price forecasting is considered as an important tool for energy-related utilities and power generation industries. The deregulation of power market, as well as the competitive financial environment, which have introduced new market players in this field, makes the electricity price forecasting problem a demanding mission. The main focus of this paper is to investigate the performance of asymmetric neuro-fuzzy network models for day-ahead electricity price forecasting. The proposed model has been developed from existing Takagi-Sugeno-Kang fuzzy systems by substituting the IF part of fuzzy rules with an asymmetric Gaussian function. In addition, a clustering method is utilised as a pre-processing scheme to identify the initial set and adequate number of clusters and eventually the number of rules in the proposed model. The results corresponding to the minimum and maximum electricity price have indicated that the proposed forecasting scheme could be considered as an improved tool for the forecasting accuracy.

5:00PM *Z Number based Neuro-Fuzzy Network for Dynamic Plant Control* [#231]

Rahib Abiyev, Near East University, Turkey

In the paper, Z number based neuro-fuzzy network (ZNFN) for control of dynamic plants is presented. Using interpolative reasoning mechanism the structure and design algorithms of ZNFN are proposed. The gradient learning algorithm is designed to update the parameters of ZNFN. The proposed ZNFN structure is tested for control of dynamic plants and the performance of

5:45PM *Double-Input Interval Type-2 Fuzzy Logic Controllers: Analysis and Design* [#159]

Andriy Sarabakha, Changhong Fu and Erdal Kayacan, Nanyang Technological University, Singapore

A significant number of investigations of type-1 and type-2 fuzzy logic controllers have revealed their exceptional ability to capture uncertainties in complex and nonlinear systems, particularly in real-time control applications. However, regardless of being type-1 or type-2, fuzzy logic controller design is still a complicated task due to the lack of a closed form solution of the output and an interpretable relationship between the control output and fuzzy logic controller design parameters, such as center or width of the membership functions. To simplify the design procedure further, we think every attempt to obtain such interpretable relationships is worthwhile. Accordingly, this paper

aims to design a double-input interval type-2 fuzzy PID controller and obtain interpretable relationships between the input and the output of the controller. Thereafter, we deploy the novel design for the control of a Y6 coaxial

tricopter unmanned aerial vehicle. Simulation results, which are realised in robot operating system (ROS) using C++ and Gazebo environment, are found to tally with the theoretical analysis and claims in the paper.

Tuesday, July 11, 8:00AM-10:00AM

Advances to Type-2 Fuzzy Logic Control

Tuesday, July 11, 8:00AM-10:00AM, Room: Normanna, Chair: Tufan Kumbasar and Hao Ying

8:00AM *On the Design and Gain Analysis of IT2-FLC with a Case Study on an Electric Vehicle* [#180]

Ahmet Sakalli and Tufan Kumbasar, AVL Research and Engineering Turkey, Turkey; Istanbul Technical University, Turkey

In this paper, we will present the gain analysis of an Interval Type-2 (IT2) Fuzzy Logic Controller (FLC) that employs the Nie-Tan method and validated our theoretical results on the control of realistic Electric Vehicle (EV) model. In this context, we firstly will present the analytical derivation of the employed IT2-FLC structure and its output in closed form. We will then investigate the gain variations with respect to the Footprint of Uncertainty (FOU) design parameter of the IT2-FLC. We will define aggressive and smooth control regions based on the gain of IT2 FLCs in comparison with its type-1 counterpart. We will also present the FOU parameter settings that obtain aggressive or smooth control actions based on derived controller gains. We will extend these gain analysis into controller design to achieve desired control action. We will present the simulation studies in which aggressive and smooth IT2-FLCs are compared and evaluated on the EV model for different control performance measures. The results will show that the presented gain analysis provides better understanding about the effect of the FOU parameter and an initiative way to tune IT2-FLC for control system applications.

8:15AM *Game of Spheros: A Real-World Pursuit-Evasion Game with Type-2 Fuzzy Logic* [#182]

Aykut Beke and Tufan Kumbasar, Istanbul Technical University, Turkey

In this paper, we will present the novel application of Type-2 (T2) fuzzy logic to solve a real-time pursuit-evasion game problem with the spherical droids Sphero 2.0 and BB8 (products of the Sphero company). The game scenario is constructed as the evader droid BB8 is controlled by a human user while the pursuer droid Sphero 2.0 is navigated through the game environment via the proposed T2 fuzzy pursuing system. The proposed T2 fuzzy pursuing system structure is composed of vision based localization, the error signal generator, T2 fuzzy strategy planner and the control system. The T2 fuzzy strategy planner is the key structure of the pursuing system since it generates the reference trajectories to be followed by the pursuer droid Sphero 2.0. In this paper, we have transformed design guidelines presented for T2 fuzzy logic controllers into two pursuing strategies for the first time in literature. The performances of the proposed T2 fuzzy strategies have been examined by providing comparative experimental results performed in the real-world game environment against a human user. We believe that this pioneer application of the T2 fuzzy logic in pursuit- evasion games will be an important step for a wider deployment in the research area of real world games.

8:30AM *Landing on the Moon with Type-2 Fuzzy Logic* [#181]

Atakan Sahin and Tufan Kumbasar, University of Strathclyde, United Kingdom; Istanbul Technical University, Turkey

In this study, we will present the novel application of Type-2 (T2) fuzzy logic to the popular video game called Lunar Lander. The proposed T2 fuzzy moon landing system structure is composed of the error signal generator and the

T2 fuzzy logic control structure which give the opportunity to transform the moon landing problem of the spaceship as a multivariable tracking control problem. The landing problem of the game can be seen as one of the classical multivariable control problems including uncertainties due to the randomization process occurring the game environment. Thus, we will employ T2 fuzzy logic controllers since they are capable of handling a high level of uncertainties. Then, by optimizing the T2 fuzzy moon landing system via the particle swarm optimization, we will show that the resulting T2 fuzzy moon landing system resulted with an adequate control and game performance in the presence of the uncertainties, disturbances and nonlinear system dynamics in comparison with its type-1 and conventional counterparts. We believe that the results of this paper will be an important step for a wider deployment of T2 fuzzy logic in the research area of computer games.

8:45AM *Application of Interval Type-2 Subsethood Neural Fuzzy Inference System in Control and Function Approximation* [#286]

Sumati Vuppuluri, Patvardhan C., Sandeep Paul, Lotika Singh and Mehar Swarup V., Dayalbagh Educational Institute, India; Cisco Systems, United States

This paper presents the application of Interval Type-2 Subsethood Neural Fuzzy Inference System (IT2SuNFIS) [1] in the area of control of a chemical plant and function approximation. In this model, a subsethood method between interval type-2 fuzzy set (IT2 FS) inputs and IT2 FS antecedents. The inputs to the system are fuzzified using IT2 FS with Gaussian primary membership function (GPMF) having identical mean but different variance. The signal aggregation of type-2 based activation is performed using product operator. This neuro-fuzzy system trains in differential evolution (DE) framework. Different DE learning strategies have been used for this purpose. During the training, different networks are generated and trained using DE methodology. The system is tested on the control of a chemical plant. Comparisons with other type-1 and type-2 neuro-fuzzy models verify the excellent control of the proposed methodology for the control of the chemical plant. The system is also tested on Hang function approximation problem. It is observed that the system performs better than other models reported in literature in terms of lesser number of free parameters; the result accuracy is similar to other models.

9:00AM *Interval Type-2 TSK Nominal-fuzzy-model-based Sliding Mode Controller Design for Flexible Air-breathing Hypersonic Vehicles* [#336]

Junlong Gao, Jianqiang Yi, Zhiqiang Pu and Chengdong Li, Institute of Automation, Chinese Academy of Sciences, China; School of Information and Electrical Engineering, Shandong Jianzhu University, China

This paper presents a novel interval type-2 TSK nominal-fuzzy-model-based sliding mode controller (IT2-TSK-NFMSMC) for flexible air-breathing hypersonic vehicle (FAHV) in order to stress robustness of the control system in dealing with data-driven based fuzzy modelling deviations, system uncertainty and disturbances. We adopt backstepping structure decomposing FAHV model into 5 control subsystems and design controllers, respectively.

More specifically, two subsystems are designed with integral sliding mode model controllers. Another three subsystems which directly coupling with flexible mode disturbances are designed with IT2-TSK-NFMSMCs by the following steps: 1) interval type-2 TSK nominal-fuzzy-models (IT2-TSK-NFM) are generated automatically by using type-2 fuzzy self-organizing methods from experiment datasets; 2) nominal model sliding mode controllers are designed based on the IT2-TSK-NFM, respectively; 3) notch filters are adopted in order to decrease the disturbance effects from the flexible modes; 4) sliding mode compensation controllers are designed through Lyapunov synthesis in order to compensate differences between IT2-TSK-NFM and real models of the FAHV. Several scenarios are studied and the simulation results validate the robustness of the proposed controllers when there exist internal flexible vibration and external system disturbances.

Advances in Soft Computing modelling for biomedical data

Tuesday, July 11, 8:00AM-10:00AM, Room: Sveva, Chair: Antonino Staiano Angelo Ciaramella and Sushmita Mitra

8:00AM *Decoy Clustering through Graded Possibilistic c-Medoids* [#499]

Alessio Ferone and Antonio Maratea, University of Naples "Parthenope", Italy

Modern methods for ab initio prediction of protein structures typically analyze multiple simulated conformations, called decoys, to find the best native-like conformations. To limit the search space, clustering algorithms are routinely used to group similar decoys, based on the hypothesis that the largest group of similar decoys will be the closest to the native state. In this paper a novel clustering algorithm, called Graded Possibilistic c-Medoids, is proposed and applied to a decoy selection problem. As it will be shown, the added flexibility of the graded possibilistic framework allows a very effective selection of the best decoys with respect to similar methods based on medoids - that is the most central points belonging to each cluster. The proposed algorithm has been compared with other c-medoids algorithms and also with SPICKER on real data, the large majority of times outperforming both.

8:15AM *Synergetic Neuro-Fuzzy Feature Selection and Classification of Brain Tumors* [#204]

Subhashis Banerjee, Sushmita Mitra and B. Uma Shankar, Indian Statistical Institute, India

Brain tumors constitute one of the deadliest forms of cancers, with a high mortality rate. Of these, Glioblastoma multiforme (GBM) remains the most common and lethal primary brain tumor in adults. Tumor biopsy being challenging for brain tumor patients, noninvasive techniques like imaging play an important role in the process of brain cancer detection, diagnosis and prognosis; particularly using Magnetic Resonance Imaging (MRI). Therefore, development of advanced extraction and selection strategies of quantitative MRI features become necessary for noninvasively predicting and grading the tumors. In this paper we extract 56 three-dimensional quantitative MRI features, related to tumor image intensities, shape and texture, from 254 brain tumor patients. An adaptive neuro-fuzzy classifier based on linguistic hedges (ANFC-LH) is developed to simultaneously select significant features and predict the tumor grade. ANFC-LH achieves a significantly higher testing accuracy (85.83%) as compared to existing standard classifiers.

9:15AM *Effect of Different FOU Shapes on the Performance in Interval Type-2 Fuzzy PI Control Systems* [#404]

Chun Ming Tommy Yip, Woei Wan Tan and Maowen Nie, Department of Electrical and Computer Engineering, National University of Singapore, Singapore; Department of Social and Cognitive Computing, Institute of High Performance Computing, Singapore

The control performance of type-2 fuzzy logic controller (IT2-FLCs) is heavily dependent on the choice of antecedent and consequent sets. However, there are no clear guidelines on how to choose suitable FOU shape to achieve the desired control requirements. This paper aims to explore how differences in FOU shapes affect the control performance by analysing three different types of antecedent fuzzy sets. They are the triangular top wide, triangular bottom wide and the trapezoidal fuzzy sets. Analytical structures of these controllers are derived. The analytical structures of the triangular bottom wide and trapezoidal controllers show more common features than triangular top wide controller. Based on the characteristics of the analytical structure, it may be hypothesised that the control performances of IT2-FLCs that use triangular bottom wide and trapezoidal antecedent IT2 fuzzy sets would be more similar than an IT2-FLC constructed by triangular top wide antecedent IT2 fuzzy sets. The hypothesis is then verified by simulation results.

8:30AM *Applications of Computing With Words in Medicine* [#154]

Aashi Jain, Divya Gupta, Garima Gupta and Swati Aggarwal, Netaji Subhas Institute of Technology, India

Computing with Words (CW) is a concept which solves problems when input is provided in form of natural language. CW is at its initial stages and is not at its full potential. Medicine is a pivotal field and CW has barely been explored here. This paper concentrates on how to use CW methods to overcome challenging problems in medicine. It especially focuses on finding a solution to help Dementia affected people whose symptoms are not curable. The latter part lists down some more ways in which CW can affect areas in medicine.

8:45AM *Camphor Odor Recognition within Unbalanced Multi-Sets* [#239]

Nouha Chaoued, Amel Borgi and Anne Laurent, Universite de Tunis El Manar, Faculte des Sciences de Tunis, LIPAH - Universite de Montpellier, LIRMM, Tunisia; Universite de Tunis El Manar, Institut Superieur d'Informatique, Faculte des Sciences de Tunis, LIPAH, Tunisia; Universite de Montpellier, LIRMM, France

In fuzzy logic context, some works deal with the camphor odor perception. In this paper, we present a novel rule-based decision system for the camphor odor recognition within unbalanced multiset. Our first contribution consists in an adaptation of fuzzy knowledge representation and inference rules to the multi-valued logic context. The second contribution concerns the improvement of the knowledge base by changing facts representation and adding new rules. This proposition provides satisfactory results in term of precision, recall, F-measure and accuracy.

9:00AM *Feature Selection based on Choquet Integral for Human Activity Recognition* [#84]

Amina Jarraya, Khedija Arour, Amel Bouzeghoub and Amel Borgi, El-Manar University, Tunisia; Carthage University, Tunisia; Paris-Saclay University, France

Human activity recognition (HAR) is an important research issue for pervasive computing that aims to identify human activities. Extracted features from raw sensors are often large and some of them can be irrelevant and redundant. Therefore, it's important to perform feature selection to select the most relevant features in order to increase the recognition accuracy.

However, classical feature selection methods are generally linear and sequential and they do not consider existing dependencies and interactions among activities (classes). To overcome this shortcoming, a feature selection based on Choquet integral for HAR is proposed in this paper. The Choquet integral is a non linear and a non additive method. It's employed to determine scores for features by modeling interactions between activities through the fuzzy measure theory. Classification results on HAR dataset using Random Forest classifier indicate that the recognition accuracy remains stable using half of the features. Moreover, classification performance is further improved.

Fuzziness in Data Science for Industrial and Manufacturing Applications

Tuesday, July 11, 8:00AM-10:00AM, Room: Santa Lucia, Chair: Luigi Troiano and S. Irene Díaz

8:00AM *Granulation of Financial Time Series for Trend Analysis and Recognition* [#604]

Pravesh Kriplani, Pukhraj Shrishrimal and Shilpa Bhide, SMC Investments and Advisors Ltd., India; Dr. B. A. Marathwada University, India; Savitribai Phule Pune University, India

Time series in finance are characterized by upside and downside movements that can be or not part of a larger trend. Trends become more obvious when we look at data points as granules and we study the relationship between them. In this paper we discuss which role granulation can have in describing the behavior of time series. In particular we investigate granules obtained by means of Ruspini partitions and we provide some examples of application.

8:15AM *Matching Media Contents with User Profiles by means of the Dempster-Shafer Theory* [#603]

Luigi Troiano, Diaz Irene and Gaglione Ciro, University of Sannio, Italy; Oviedo University, Spain; Sky Italia, Italy

The media industry is increasingly personalizing the offering of contents in attempt to better target the audience. This requires to analyze the relationships that goes established between users and content they enjoy, looking at one side to the content characteristics and on the other to the user profile, in order to find the best match between the two. In this paper we suggest to build that relationship using the Dempster-Shafer's Theory of Evidence, proposing a reference model and illustrating its properties by means of a toy example. Finally we suggest possible applications of the model for tasks that are common in the modern media industry.

8:30AM *Aggregation of Gravitational Wave Detections by means of T-norms* [#605]

Elena Mejuto Villa, Innocenzo Pinto and Luigi Troiano, University of Sannio, Italy

We propose the application of triangular norms in the time-frequency domain, as a general framework for implementing consistency tests between the data gathered by different non collocated GW detectors, for denoising and signal isolation purposes

8:45AM *An Ensemble Data-Driven Fuzzy Network for Laser Welding Quality Prediction* [#175]

Adrian Rubio-Solis and George Panoutsos, The University of Sheffield, United Kingdom

This paper presents an Ensemble Data-Driven Fuzzy Network (EDDFN) for laser welding quality prediction that is composed of a number of strategically selected Data-Driven Fuzzy Models (DDFMs). Each model is trained by an Adaptive Negative Correlation Learning approach (ANCL). A monitoring system provides quality-relevant information of the laser beam spectrum and the geometry of the melt pool. This information is used by the proposed ensemble model to assist in the prediction of the welding quality. Each DDFM is based on three conceptual components, i.e. a selection procedure of the

most representative welding information, a granular comprehension process of data and the construction of a fuzzy reasoning mechanism as a series of Radial Basis Function Neural Networks (RBF-NNs). The proposed model aims at providing a fuzzy reasoning engine that is able to preserve a good balance between transparency and accuracy while improving its prediction properties. We apply the EDDFN to a real case study in manufacturing industry for the prediction of welding quality. The corresponding results confirm that the EDDFN provides better prediction properties compared to a single DDFM with an overall prediction performance >78%.

9:00AM *ELIGERE: a Fuzzy AHP Distributed Software Platform for Group Decision Making in Engineering Design* [#520]

Stanislao Grazioso, Mateusz Gospodarczyk, Selvaggio Mario, Marzullo Domenico and Di Gironimo Giuseppe, University of Naples Federico II, Italy; University of Rome Tor Vergata, Italy

This paper presents ELIGERE, a new open-source distributed software platform for group decision making in engineering design. It is based on the fuzzy analytical hierarchy process (fuzzy AHP), a multiple criteria decision making method used in group selection processes to rank a discrete set of alternatives with respect to some evaluation criteria. ELIGERE is built following the paradigm of distributed cyber-physical systems. It provides several features of interest in group decision making problems: a web-application where experts express their opinion on the alternatives using the natural language, a fuzzy AHP calculation module for transforming qualitative into quantitative data, a database for collecting both the experts' answers and the results of the calculations. The resulting software platform is: distributed, interactive, multi-platform, multi-language and open-source. ELIGERE is a flexible cyber-physical information system useful in various multiple criteria decision making problems: in this paper we highlight its key concepts and illustrate its potential through a case study, i.e., the optimum selection of design alternatives in a robotic product design.

9:15AM *Designing Optimal Fuzzy-compensator-enhanced Sliding Controller for Train-car Semi-active Suspensions* [#238]

Sy Dzung Nguyen, Quoc Hung Nguyen and Nang Toan Truong, Ton Duc Thang University, Viet Nam; Vietnam-German University, Viet Nam; Industrial University of Ho Chi Minh City, Viet Nam

An optimal fuzzy disturbance observer-enhanced sliding mode controller (FDO-SMC) for magneto-rheological damper (MRD)-based semi-active train-car suspensions (MRD-TSs) subjected uncertainty and disturbance (UAD) whose variability rate may be high but bounded is proposed. The two main parts of the FDO-SMC are an adaptive sliding mode controller (aSMC) and an optimal fuzzy disturbance observer (oFDO). First, initial structures of the sliding mode controller (SMC) and disturbance observer (DO) are built. Adaptive update laws for the SMC and DO are then set up synchronously via Lyapunov stability analysis with a used parameter constraint mechanism. An

optimal fuzzy system (oFS) is designed to implement fully the constraint mechanism so as to guarantee for the stable converging to the desired state even if the UAD variability rate increases in a given range. As a result, the aSMC and the oFDO are created from the SMC and DO. The compared

simulation surveys reflected that the positive competence to stamp out and isolate vibration with the lower consumed power is the main advantage of the proposed controller.

Engineering Applications of Fuzzy Sets-I

Tuesday, July 11, 8:00AM-10:00AM, Room: Aragonese, Chair: José Luis Verdegay and David Pelta

8:00AM *Improved optimality conditions for fuzzy mathematical programming* [#222]

Rafaela Osuna-Gomez, Beatriz Hernandez-Jimenez, Yurilev Chalco-Cano and Gabriel Ruiz-Garzon, Universidad de Sevilla, Spain; Universidad Pablo de Olavide, Spain; Universidad de Tarapaca, Chile; Universidad de Cadiz, Spain

In this work we study optimization problems where both objective and constraints are given by fuzzy functions. In order to solve them, we first prove that such problems are equivalent to fuzzy optimization problems where the constraints are non-fuzzy (crisp) functions. Besides we prove a new and appropriate Karush-Kuhn-Tucker type necessary optimality condition based on the gH-differentiability and that has many computational advantages that we describe. The gH-derivative for fuzzy functions is a more general notion than Hukuhara and level-wise derivatives ones that are usually used in fuzzy optimization so far, in the sense that it can be applied to a wider number of fuzzy function classes than above concepts. With this new differentiability concept, we prove a KKT-type necessary optimality condition for fuzzy mathematical programming problems that is more operational and less restrictive than the few ones we can find in the literature so far.

8:15AM *Analysis of Fuzzy Multi-Objective Location Problems by using Open Georeferenced Data* [#420]

Christopher Exposito-Izquierdo, Airam Exposito-Marquez, Belen Melian-Batista and J. Marcos Moreno-Vega, Universidad de La Laguna, Spain

This paper presents a general solution approach based on exploiting open georeferenced data by using a Geographic Information System. The suitability of this approach is assessed on a new practical multi-objective optimization problem arisen in the context of the location theory. It seeks to determine the locations of a known number of electric vehicle sharing stations in the city of San Francisco while considering fuzzy criteria. These new stations are the departure points of touristic routes aimed at visiting the most representative points of interest around the city. The computational experiments indicate that the solution approach can be easily used as an effective tool to support decision making processes in related problems.

8:30AM *Applicability of various wavelet families in fuzzy classification of access networks' telecommunication lines* [#423]

Szilvia Nagy, Ferenc Lilik and Laszlo T. Koczy, Szechenyi Istvan University, Hungary; Szechenyi Istvan University, Budapest University of Technology and Economics, Hungary

The future of the smart society sets challenges for all types of existing telecommunication networks and links. For ensuring the optimal utilization of these networks precise performance predictions are necessary, especially in case of the symmetrical access networks with rather limited transmission capacity. It is also important to harness the already established infrastructure as long as it is technically possible, so that the use of the environmental resources would be minimal and the economical advantages would be maximal. In performance prediction of telecommunication links the high-dimensional input data, like the insertion loss spectrum, should be compressed. After reducing the dimension of the antecedent set, a fuzzy inference can be carried out for each of the lines. As the number of lines

used for building the fuzzy sets is finite and the supports of the fuzzy set do not cover the whole space, a stabilized KH interpolation is used in the decision process. Wavelets constitute the basis of methods for compressing and analyzing data in many fields of science and technology. For the reduction of the input dimension, wavelets proved to be an effective tool. The applicability of various wavelet families with different sizes of filter coefficient sets are tested in the following considerations, with the result, that the wavelet type does not play an essential role as well as the length of the wavelets. Only the deepness of the wavelet transform influences essentially the goodness of the prediction: the remaining number of points should be 4 after the transformation.

8:45AM *A fuzzy GRASP algorithm for solving a Tourist Trip Design Problem* [#439]

Julio Brito, Airam Exposito-Marquez and Jose A. Moreno, Universidad de La Laguna, Spain

This work considers a route-planning problem in the tourism sector, the Tourist Trip Design Problem which aims to design the routes that maximize the satisfaction of the visited points of interest. This paper proposes a model of a multi-day planning problem for sightseeing. In order to solve this optimization problem, a new Fuzzy Greedy Randomized Adaptive Search Procedure is developed to obtain high-quality solutions. Fuzzy approach is used to evaluate the point of interest to be included in the solution considering the ambiguity and imprecision of promising point of interest to visit and satisfactory solutions. The computational experiments indicate the fuzzy GRASP is able to report competitive solutions by using short computational times.

9:00AM *Fuzzy Theory and Quality Control Charts* [#466]

Maria Pastuizaca, ESPOL Polytechnic University, Escuela Superior Politecnica del Litoral, ESPOL, Facultad de Ciencias Naturales y Matematicas, Ecuador

Quality control charts are one of the most important tools of statistical process control, used to analyze the behavior of different processes and to predict possible production failures. The use of a fuzzy approach in the design of control charts has allowed to improve the performance of traditional charts, as well as to be possible of a simple approach for the design of control charts for linguistic variables with multinomial distribution for both, the univariate case as for the multivariate case. In this paper we will show some of the main proposals of fuzzy control charts found in the literature.

9:15AM *Application of the Support Function and the Steiner Point on the Study of Interference Alignment Channel*. [#484]

Ricardo Augusto Watanabe and Cibele Cristina Trinca Watanabe, IMECC, Brazil; FEEC, Brazil

Interference is usually viewed as an obstacle to communication in wireless networks. Therefore, we describe a way to find a doubly infinite nested lattice partition chain for the real dimension 2 in order to realize interference alignment onto these lattices and a procedure to find the minimum solution of the mean square error related to the corresponding channel quantization. Besides, we propose a new methodology based on the support function and Steiner points of fuzzy vectors to find the closest point of a coset in a lattice. Such a methodology is flexible enough to combine the fuzzy characterization with the geometric insights and it is able to maintain the inherent stochastic nature of the wireless communication networks.

Applications of aggregation functions I

Tuesday, July 11, 8:00AM-10:00AM, Room: Catalana, Chair: Radko Mesiar, Javier Montero, Irina Perfilieva Humberto Bustince

8:00AM *Soft Color Morphology* [#27]

Pedro Bibiloni, Gonzalez-Hidalgo Manuel and Massanet Sebastia, University of the Balearic Islands, Spain

Morphological operators have been used extensively when dealing with binary or grayscale images, but there is no general-purpose approach for multivariate images that meets the expectations of practitioners under different circumstances. Although several approaches have been proposed, state-of-the-art applications tend to process channels independently, obviating interchannel correlation. In this work, we introduce a new definition of erosion and dilation that can handle images with any number of channels, study their theoretical properties and analyse its behaviour. It is based on the Fuzzy Mathematical Morphology, from which it inherits essential theoretical properties. Our operators consider the first channel to evaluate a pixel's importance, but handles all channels to generate coherent outputs. It successfully processes natural images in the $L^*a^*b^*$ space and can also avoid the creation of new chromatic values, specially important for hyperspectral imagery. We provide, thus, a general and well-founded framework to process color images with morphological operators.

8:15AM *Bilinear Equations and Fuzzy Image Comparison* [#40]

Ferdinando Di Martino and Salvatore Sessa, Department of Architecture, Universita' degli Studi di Napoli Federico II, Italy

We present an image comparison method based on the greatest solution of a system of bilinear fuzzy relation equations $A*B = B*x$, where $*$ is the max-min composition, A and B are the compared images, normalized in [0,1] and considered as fuzzy relations, and x is an unknown vector. Due to symmetry, A (resp. B) could be the original image and B (resp. A) is an image modified of A (resp. B) (for instance, either noised or watermarked). Our index is more robust than other two comparison indexes already known in literature.

8:30AM *Robust Image Denoising and Smoothing with Generalised Spatial-Tonal Averages* [#85]

Tim Wilkin and Gleb Beliakov, Deakin University, Australia

This article investigates image filtering and smoothing from the perspective of a recent generalisation of the notion of aggregation functions in fuzzy systems, called pre-aggregation functions. Mixture functions describing a broad class of robust spatial-tonal filters and smoothers are derived using penalty-based methods. Several existing filters are re-derived using this approach and several novel filters are proposed, which are able to better handle filtering in contexts where the pixel to be filtered is itself an outlier in the local neighbourhood. The proposed class of Robust Bilateral Filters formalises and generalises a recent result of Chaudhury, who noted that using a filtered version of an image to compute tonal weights for a Bilateral Filter gave more robust denoising. Filter performance is validated using standard test images and quantified using peak signal-to-noise ratio and

visual similarity, finding novel filters that exceed the performance of the standard Bilateral Filter.

8:45AM *A Hybrid Image Compression Algorithm Based on JPEG and Fuzzy Transform* [#359]

Petr Hurtik and Irina Perfilieva, IRAFM, OSU, Czech Republic

We propose a new hybrid image compression algorithm which combines the F-transform and the JPEG. At first, we apply the direct F-transform and then, the JPEG compression. Conversely, the JPEG decompression is followed by the inverse F-transform to obtain the decompressed image. This scheme brings three benefits: (i) the direct F-transform filters out high frequencies so that the JPEG can reach a higher compression ratio; (ii) the JPEG color quantization can be omitted in order to achieve greater decompressed image quality; (iii) the JPEG-decompressed image is processed by the inverse F-transform w.r.t. the adjoint partition almost lossless. The paper justifies the proposed hybrid algorithm by benchmarks which show that the hybrid algorithm achieves significantly higher decompressed image quality than the JPEG.

9:00AM *Image Vignetting Reduction via a Maximization of Fuzzy Entropy* [#510]

Laura Lopez-Fuentes, Sebastia Massanet and Manuel Gonzalez-Hidalgo, University of the Balearic Islands, Spain

In many computer vision applications, vignetting is an undesirable effect which must be removed in a pre-processing step. Recently, an algorithm for image vignetting correction has been presented by means of a minimization of log-intensity entropy. This method relies on an increase of the entropy of the image when it is affected with vignetting. In this paper, we propose a novel algorithm to reduce image vignetting via a maximization of the fuzzy entropy of the image. Fuzzy entropy quantifies the fuzziness degree of a fuzzy set and its value is also modified by the presence of vignetting. The experimental results show that this novel algorithm outperforms in most cases the algorithm based on the minimization of log-intensity entropy both from the qualitative and the quantitative point of view.

9:15AM *On the Use of Choquet Integrals in the Reduction of the Size of L-Fuzzy Contexts* [#291]

Cristina Alcalde and Ana Burusco, University of the Basque Country, Spain; Universidad Publica de Navarra, Spain

Studies about the reduction of the size of the L-fuzzy concept lattices have been addressed over the past. The number of objects and attributes of the L-fuzzy context is one of the most important factors that influence the size of the L-fuzzy concept lattice. In this paper, we tackle the problem of reducing the L-fuzzy context size. In order to do this, Choquet integrals can be a good tool for aggregating values. The possibility of giving importance not only to the individual observations, but also to the groups provides an appropriate way to solve the problem.

DM IV: Fuzzy MCDA Applications

Tuesday, July 11, 8:00AM-10:00AM, Room: Giardino, Chair: Rosa Rodríguez Javier Cabrerizo

8:00AM *Z-TOPSIS Approach for Performance Assessment using Fuzzy Similarity* [#121]

Ku Muhammad Naim Ku Khalif, Alexander Gegov and Ahmad Syafadhli Abu Bakar, University of Portsmouth, United Kingdom; University of Malaya, Malaysia

-- This paper presents fuzzy similarity based Fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) for z-numbers. The classical fuzzy TOPSIS techniques use closeness coefficient to determine the rank order by calculating Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS) simultaneously. The authors propose fuzzy similarity to replace closeness coefficient by doing ranking evaluation. Fuzzy similarity is used to calculate the similarity between two fuzzy ratings (FPIS and FNIS). Fuzziness is not sufficient enough when dealing with real information and a degree of reliability of the information is very critical. Hence, the implementation of z-numbers is taken into consideration as they can capture better the knowledge of human being and are extensively used in uncertain information development to deal with linguistic decision making problems. A numerical example is given to illustrate the application of the proposed technique in ranking company performance assessment. The results show that it is highly feasible to use the proposed technique in performance assessment.

8:15AM *Cloud Computing Technology Selection Based on Interval Valued Intuitionistic Fuzzy Group Decision Making using MULTIMOORA Approach* [#475]

Gulcin Buyukozkan, Fethullah Gocer and Orhan Feyzioglu, Galatasaray University, Turkey

Cloud computing technology (CCT) provides virtual services accessible to its users from anywhere based on subscriptions with attractive costs wherever they are. It also brings many different benefits to businesses as well as the public by saving them time and resources that would be needed for establishing and operating their own Information Technology infrastructure. For this reason, the objectives of this study are to identify important decision criteria and sub criteria that are relevant to the CCT selection problem; to provide an effective framework to evaluate and select the most appropriate CCT and to apply proposed approach through an empirical study. Technology selection in general is a complicated multi-criteria problem that concerns both quantitative and qualitative parameters, which are usually conflicting and uncertain. Interval Valued Intuitionistic Fuzzy (IVIF) set is a powerful method to cope with uncertainty by taking both degree of membership and nonmembership function in an interval. Therefore, a multi-criteria analysis and solution methodology is presented, which incorporates decision makers' insufficient knowledge and other pressures involved in the evaluation with the help of an extension of MULTIMOORA (Multi-objective Optimization by Ratio Analysis plus the Full Multiplicative Form) technique in order to rank alternatives for handling imprecise data in selecting the most suitable CCT. To demonstrate the usability of the proposed technique, an illustrative study is also given.

8:30AM *Decision-Making on Adoption of Cloud Computing in E-Commerce Using Fuzzy-TOPSIS* [#48]

Osama Sohaib and Mohsen Naderpour, University of Technology Sydney, Australia

Cloud computing promises enhanced scalability, flexibility, and cost-efficiency. In practice, however, there are many uncertainties about the usage of cloud computing resources in the e-commerce context. As e-commerce is dependent on a reliable and secure online store, it is important for decision makers to adopt an optimal cloud computing mode (Such as SaaS, PaaS and IaaS). This study assesses the factors associated with cloud-based e-commerce based on TOE (technological, organizational, and environmental) framework using multicriteria decision-making technique (Fuzzy TOPSIS). The results show that Fuzzy TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) approach proposes software-as-a-service (SaaS) as the best choice for e-commerce business.

8:45AM *A Multicriteria Outranking Modeling Approach for Personnel Selection* [#253]

Diego Alonso Gastelum Chavira, Juan Carlos Leyva Lopez, Jesus Jaime Solano Noriega and Javier Leonardo Pereira Retamales, CONACYT - UdeO, Mexico; Universidad de Occidente, Mexico; Instituto Tecnológico y de Estudios Superiores de Monterrey, Mexico

Personnel selection constitutes an important decision making problem that determines, to a large degree, the competitiveness and performance of organizations. The personnel selection process works with the vacancy requirements and the available information concerning to the applicants. Complicating this process, we have diverse competencies or skills to evaluate the candidates for a vacancy, which can be modeled as a multicriteria problem. In this article, we propose a multicriteria approach to solve instances of personnel selection problem. For that, we use a software called SADGAGE, which solves instances of the multicriteria ranking problem with decreasing preferences direction about the preferences of a decision maker.

9:00AM *An Extension of ARAS Methodology Based on Interval Valued Intuitionistic Fuzzy Group Decision Making for Digital Supply Chain* [#472]

Gulcin Buyukozkan and Fethullah Gocer, Galatasaray University, Turkey

Everyone knows that technology altered profoundly the way we communicate and interact with the world, from personal computers to mobile devices. The impact of emerging new technologies affects every industry, and supply chain or logistics are no exception. Digital Supply Chain (DSC) create added various benefits to companies, financial or otherwise. Today, an emerging trend in supply chain management worldwide is a movement of the focus from that of classical supply chain to that of DSC. Modern organizations therefore shall interact with their dealers through DSC processes for production and delivery operations of goods and services. Due to its multi criteria nature, this study proposes a novel approach to evaluate supplier selection process under DSC environment for group decision making in an uncertain environment. The proposed framework combines for the first time the Interval Valued Intuitionistic Fuzzy (IVIF) Analytic Hierarchy Process (AHP) to evaluate criteria weights and IVIF Additive Ratio Assessment (ARAS) methodology for alternative assessment procedure. The paper also analyzes the selection of a suitable supplier in a real case study from Turkey to demonstrate the validity of the proposed approach.

9:15AM *Evaluating Performance Measurements in Supplier Selection Decisions: A Fuzzy-Set Based Goal Fitting Approach* [#140]

Margaret F. Shipley, Qing Cao and Jonathan Davis, University of Houston Downtown, United States

This exploratory study attempts to prove the premise that performance measurements are instrumental in the often inconsistent and dynamic supplier selection problem. The fundamental Supply Chain Management (SCM) phases of Plan, Source, Make, and Deliver and at what level of managerial decision making (Operational, Tactical or Strategic) are the performance measures considered in supplier selection and potential buyer-supplier partnerships. Utilizing survey responses, the scores of over 400 buyers comparing seven suppliers in a competitive, electronics industry were consolidated across the four phases of SCM then within each phase, the responses and scores were again mapped into the level of decision making involved. Fuzzy probabilities of fit into intervals for the average scores were determined and goals based on beliefs attributed to the goals were set. Results confirmed that the Source phase was most important to buyers followed by the Plan phase. The level of decision making was highlighted as Tactical.

Fuzzy Natural Language Processing I

Tuesday, July 11, 8:00AM-10:00AM, Room: Borbonica, Chair: Joao Paulo Carvalho Keeley Crockett

8:00AM *Detecting relevant tweets in very large tweet collections: the London Riots case study* [#403]

Joao Paulo Carvalho, Hugo Rosa and Fernando Batista, INESC-ID / Instituto Superior Tecnico, Universidade de Lisboa, Portugal; INESC-ID / ISCTE-IUL, Portugal

In this paper we propose to approach the subject of detecting relevant tweets when in the presence of very large tweet collections containing a large number of different trending topics. We use a large database of tweets collected during the 2011 London Riots as a case study to demonstrate the application of the proposed techniques. In order to extract relevant content, we extend, formalize and apply a recent technique, called Twitter Topic Fuzzy Fingerprints, which, in the scope of social media, outperforms other well known text based classification methods, while being less computationally demanding, an essential feature when processing large volumes of streaming data. Using this technique we were able to detect 45% additional relevant tweets within the database.

8:15AM *Application of Fuzzy Semantic Similarity Measures to Event Detection Within Tweets* [#163]

Keeley Crockett, Naeemeh Adel, James OShea, Alan Crispin, David Chandran and Joao Paulo Carvalho, Manchester Metropolitan University, United Kingdom; Kings College London, United Kingdom; Technical University of Lisbon, Portugal

This paper examines the suitability of applying fuzzy semantic similarity measures (FSSM) to the task of detecting potential future events through the use of a group of prototypical event tweets. FSSM are ideal measures to be used to analyse the semantic textual content of tweets due to the ability to deal equally with not only nouns, verbs, adjectives and adverbs, but also perception based fuzzy words. The proposed methodology first creates a set of prototypical event related tweets and a control group of tweets from a data source, then calculates the semantic similarity against an event dataset compiled from tweets issued during the 2011 London riots. The dataset of tweets contained a proportion of tweets that the Guardian Newspaper publically released that were attributed to 200 influential Twitter users during the actual riot. The effects of changing the semantic similarity threshold are investigated in order to evaluate if Twitter tweets can be used in conjunction with fuzzy short text similarity measures and prototypical event related tweets to determine if an event is more likely to occur. By looking at the increase in frequency of tweets in the dataset, over a certain similarity threshold when matched with prototypical event tweets about riots, the results have shown that a potential future event can be detected.

8:30AM *Fuzzy Approach for Sentiment Analysis* [#290]

Chris Jefferson, Han Liu and Mihaela Cocca, School of Computing, University of Portsmouth, United Kingdom

Sentiment analysis aims to identify the polarity of a document through natural language processing, text analysis and computational linguistics. Over the

last decade, there has been much focus on sentiment analysis as the data available on-line has grown exponentially to include many sentiment based documents (reviews, feedback, articles). Many approaches consider machine learning techniques or statistical analysis, but there has been little use of the fuzzy classifiers in this field especially considering the ambiguity of language and the suitability of fuzzy approaches to deal with this ambiguity. This paper proposes a fuzzy rule based system for sentiment analysis, which can offer more refined outputs through the use of fuzzy membership degrees. We compare the performance of our proposed approach with commonly used sentiment classifiers (e.g. Decision Trees, Naive Bayes) which are known to perform well in this task. The experimental results indicate that our fuzzy-based approach performs marginally better than the other algorithms. In addition, the fuzzy approach allows the definition of different degrees of sentiment without the need to use a larger number of classes.

8:45AM *Neutrality in the Sentiment Analysis Problem Based on Fuzzy Majority* [#587]

Ana Valdivia, Maria Victoria Luzon and Francisco Herrera, University of Granada, Spain

In the Sentiment Analysis area, several Sentiment Analysis Methods are able to extract different polarities from written text with different rates. As it is known, the vote of majority has a high impact in decision making. We propose the use of Induced Ordered Weighted Averaging operators based on fuzzy majority for aggregating polarities from several Sentiment Analysis Methods. The main contribution of this work is to set neutrality on opinions guided by fuzzy majority. We aim to improve classification results by removing those neutral reviews labelled by a consensus of a collection.

9:00AM *Fuzzy Classification-Based Emotional Context Recognition from Online Social Networks Messages* [#470]

Imen Ben Sassi, Sadok Ben Yahia and Sehl Mellouli, Faculty of Sciences of Tunisia, Tunisia; Laval University, Canada

Over the past several years, social networking services or micro-blogs have become ubiquitously accessible anytime and contain users' opinions expressed in the form of short text messages. In this paper, we introduce a new automatic approach named FEmoRec for emotional context recognition from online social networks that applies a semantic similarity measure based on Multi-Layer Perceptron Neural Net Model. We rely on the assumption that a tweet may belong to many emotional categories with different membership degrees. We classify the tweet by computing an emotion vector that represents the tweet's fuzzy membership values to Ekman's emotion classes. Carried out experiments emphasize the relevance of our proposal, compared to other methods.

Handling Uncertainties in Big Data by Fuzzy Systems

Tuesday, July 11, 8:00AM-10:00AM, Room: Auditorium, Chair: Guangquan Zhang, Farookh Khadeer Hussain Jie Lu

8:00AM *A Fuzzy Virtual Machine Workload Prediction Method for Cloud Environments* [#109]

Fahimeh Ramezani and Mohsen Naderpour, University of Technology Sydney, Australia

Due to the dynamic nature of cloud environments, the workload of virtual machines (VMs) fluctuates leading to imbalanced loads and utilization of virtual and physical cloud resources. It is, therefore, essential that cloud providers accurately forecast VM performance and resource utilization so they can appropriately manage their assets to deliver better quality cloud services on demand. Current workload and resource prediction methods forecast the workload or CPU utilization pattern of the given web-based applications based on their historical data. This gives cloud providers an indication of the required number of resources (VMs or CPUs) for these applications to optimize resource allocation for software as a service (SaaS) or platform as a service (PaaS), reducing their service costs. However, historical data cannot be used as the only data source for VM workload predictions as it may not be available in every situation. Nor can historical data provide information about sudden and unexpected peaks in user demand. To solve these issues, we have developed a fuzzy workload prediction method that monitors both historical and current VM CPU utilization and workload to predict VMs that are likely to be performing poorly. This model can also predict the utilization of physical machine (PM) resources for virtual resource discovery.

8:15AM *A Fuzzy Approach to Detect Spammer Groups* [#151]

Quynh Ngoc Thuy Do, Farookh Khadeer Hussain and Bang The Nguyen, University of Technology Sydney, Australia; Digivizer, Australia

Cloud computing has been advancing at an impressive rate in recent years and is likely to increase more and more in the near future. New services are being developed constantly, such as cloud infrastructure, security and platform as a service, to name just a few. Due to the vast pool of available services, review websites have been created to help customers make decisions for their business. This leads to some reviewers taking advantage of these tools to promote the providers that hire them or to discredit competitors. These reviewers can either act individually or cooperate with each other. When reviewers collude to promote one product or defame another, they are called spammer groups. In this paper, we present an approach to identify spammer groups. First, a network-based method is used to identify individual spam reviewers. Then, a fuzzy k-means clustering algorithm is used to find the group that they belong to. A case study that suggests which group an incorrect review belongs to is provided to further understand the new method.

8:30AM *Enhanced Word Embedding Similarity Measure by Fuzzy Rule for Query Expansion* [#156]

Qian Liu, Heyan Huang, Jie Lu, Yang Gao and Guangquan Zhang, Beijing Institute of Technology, University of Technology Sydney, China; Beijing Institute of Technology, China; University of Technology Sydney, Australia

Query expansion has been widely used to select additional words that are related to the original query words in the field of information retrieval. In this paper, we present a novel query expansion method that jointly uses fuzzy rules and a word embedding similarity calculation. The expansion words are generated using a word embedding method and selected according to their semantic similarity to the original query. Fuzzy rules are used to enhance the word similarity calculations and reweight expansion words. When measuring and ranking the relevance of a retrieved document, the original query and the expansion words with their weights are considered. We conduct experiments on the query expansion in document ranking tasks. Experimental results from the document ranking task show that the proposed method is able to significantly outperform state-of-the-art baseline methods.

8:45AM *Detecting Overlapping Protein Complexes in Dynamic Protein-Protein Interaction Networks by Developing a Fuzzy Clustering Algorithm* [#170]

Ruiping Yin, Kan Li, Guangquan Zhang and Jie Lu, Beijing Institute of Technology, China; University of Technology Sydney, Australia

Protein complexes play important roles in protein-protein interaction networks. Recent studies reveal that many proteins have multiple functions and belong to more than one different complexes. To get better complex division, we need to consider time-dependent information of networks. However, only few studies can be found to concentrate on detecting overlapping clusters in time-dependent networks. To solve this problem, we propose integrated model of time-dependent network (IM-TDN) to describe time-dependent networks. On the base of this model, we propose similarity based dynamic fuzzy clustering (SDFC) algorithm to detect overlapping clusters. We apply the algorithm to synthetic data and real world protein-protein interaction network dataset. The results showed that our algorithm by using the model which we proposed achieved better results over the state-of-the-art baseline algorithms.

9:00AM *Fuzzy Rule-based Transfer Learning for Label Space Adaptation* [#263]

Hua Zuo, Guangquan Zhang, Witold Pedrycz and Jie Lu, University of Technology Sydney, Australia; University of Alberta, Canada

As the age of big data approaches, methods of massive scale data management are rapidly evolving. The traditional machine learning methods can no longer satisfy the exponential development of big data; there is a common assumption in these data-driving methods that the distribution of both the training data and testing data should be equivalent. A model built using today's data will not adequately address the classification tasks tomorrow if the distribution of the data item values has changed. Transfer learning is emerging as a solution to this issue, and many methods have been proposed. Few of the existing methods, however, explicitly indicate the solution to the case where the labels' distributions in two domains are different. This work proposes the fuzzy rule-based methods to deal with transfer learning problems where the discrepancy between the two domains shows in the label spaces. The presented methods are validated in both the synthetic and real-world datasets, and the experimental results verify the effectiveness of the introduced methods.

9:15AM *Using multi-granular fuzzy linguistic modelling methods for supervised classification learning purposes* [#50]

Juan Antonio Morente-Molinera, Jozsef Mezei, Christer Carlsson and Enrique Herrera-Viedma, Universidad Internacional de la Rioja, Spain; Lappeenranta University of Technology, Finland; Abo Akademi University, Finland; University of Granada, Spain

Classification learning is a very complex process whose success and failure ratio depends on a high amount of elements. One of them is the representation mean used for the data that is employed in the process. Granularity of the data used for classification learning purposes can affect dramatically the success and failure ratio of the obtained classification. In this paper, multi-granular fuzzy linguistic modelling methods are applied over the classification learning data in order to modify their granularity and increase the classification success ratio. Thanks to multi-granular fuzzy linguistic modelling methods, it is possible to automatically modify the data granularity in order to determine which data representation is the one that provides the better classification results in the learning process.

Tuesday, July 11, 1:30PM-3:30PM

Type-2 Fuzzy Sets and Systems Applications-I

Tuesday, July 11, 1:30PM-3:30PM, Room: Normanna, Chair: Christian Wagner and Jon Garibaldi

1:30PM *A Type-2 Fuzzy Logic System for Event Detection in Soccer Videos* [#76]

Song Wei and Hagrah Hani, University of Essex, United Kingdom

Sequences classification problems in recorded videos are often very complex and have too much uncertainty. In many application domains, such as video event activity detection, sequences of events occurring over time need to be studied in order to summarize the key events from the video clips. In most existing adaptive sequences classification systems, Dynamic Time Warping (DTW) and Gaussian Mixture Mode (GMM) are used as the core techniques in measuring similarity between two temporal sequences, which may vary in speed. Hence, there is a need to develop video event detection systems capable of classifying important events within long video sequences. This paper presents a novel system based on DTW and Interval Type-2 Fuzzy Logic Systems employing the Big Bang Big Crunch (BB-BC) algorithm for video activity detection and classification of critical events from the large-scale data of soccer videos.

1:45PM *Elliptic Membership Functions and the Modeling Uncertainty in Type-2 Fuzzy Logic Systems As Applied to Time Series Prediction* [#119]

Erdal Kayacan, Simon Coupland, Robert John and Mojtaba Khanesar, Nanyang Technological University, Singapore; De Montfort University, United Kingdom; University of Nottingham, United Kingdom; Semnan University, Iran

In this paper, our aim is to compare and contrast various ways of modeling uncertainty by using different type-2 fuzzy membership functions available in literature. In particular we focus on a novel type-2 fuzzy membership function, -- "Elliptic membership function". After briefly explaining the motivation behind the suggestion of the elliptic membership function, we analyse the uncertainty distribution along its support, and we compare its uncertainty modeling capability with the existing membership functions. We also show how the elliptic membership functions perform in fuzzy arithmetic. In addition to its extra advantages over the existing type-2 fuzzy membership functions such as having decoupled parameters for its support and width, this novel membership function has some similar features to the Gaussian and triangular membership functions in addition and multiplication operations. Finally, we have tested the prediction capability of elliptic membership functions using interval type-2 fuzzy logic systems on US Dollar/Euro exchange rate prediction problem. Throughout the simulation studies, an extreme learning machine is used to train the interval type-2 fuzzy logic system. The prediction results show that, in addition to their various advantages mentioned above, elliptic membership functions have comparable prediction results when compared to Gaussian and triangular membership functions.

2:00PM *Efficient Modeling and Representation of Agreement in Interval-Valued Data* [#130]

Timothy Havens, Christian Wagner and Anderson Derek, Michigan Technological University, United States; Mississippi State University, United States

Recently, there has been much research into effective representation and analysis of uncertainty in human responses, with applications in cyber-security, forest and wildlife management, and product development, to name a few. Most of this research has focused on representing the response uncertainty as intervals, e.g., "I give the movie between 2 and 4 stars." In this

paper, we extend upon the model-based interval agreement approach (IAA) for combining interval data into fuzzy sets and propose the efficient IAA (eIAA) algorithm, which enables efficient representation of and operation on the fuzzy sets produced by IAA (and other interval-based approaches, for that matter). We develop methods for efficiently modeling, representing, and aggregating both crisp and uncertain interval data (where the interval endpoints are intervals themselves). These intervals are assumed to be collected from individual or multiple survey respondents over single or repeated surveys; although, without loss of generality, the approaches put forth in this paper could be used for any interval-based data where representation and analysis is desired. The proposed method is designed to minimize loss of information when transferring the interval-based data into fuzzy set models and then when projecting onto a compressed set of basis functions. We provide full details of eIAA and demonstrate it on real-world and synthetic data.

2:15PM *A Type-2 Fuzzy Logic System for Engineers Estimation in the Workforce Allocation Domain* [#171]

Emmanuel Ferreyra, Hani Hagrah, Ahmed Mohamed and Gilbert Owusu, University of Essex, United Kingdom; British Telecom, United Kingdom

Supplier companies aim to pursue an efficient resource allocation to different jobs over specific times and other constraints. Dynamic and unstructured environments and real-world situations incorporate a large amount of uncertainties which are difficult to model. This paper proposes a type-2 Fuzzy Logic System (FLS) for estimating the extra number of engineers required to allocate a certain number of jobs. The type-2 FLS was trained from the knowledge extracted dynamically from input data in order to estimate corresponding outputs for unseen data. The proposed methodology has been applied to real-world service provider industry in the workforce allocation domain. The system generated sensible results which outperformed the type-1 fuzzy logic based counterpart over unseen data.

2:30PM *A Type-2 Fuzzy Logic Based System for Asset Geolocation within Augmented Reality Environments* [#378]

Anasol Pena-Rios, Hani Hagrah, Gilbert Owusu and Michael Gardner, University of Essex, United Kingdom; British Telecom, United Kingdom

This paper presents a type-2 Fuzzy Logic System (FLS) to support technical employees in finding company's assets in outdoor settings. The system provides the user with directions for asset location by comparing his/her current position with assets' location in real-time, giving auditory and visual feedback via a Head Mounted Display (HMD). We carried out 35 path explorations in a predefined area to test the system. The results indicated that the proposed type-2 fuzzy logic produces better performance than the type-1 based fuzzy system, giving more precise indications to reach asset's position.

2:45PM *A General Type-2 Fuzzy Set Induced Single Trial P300 Detection* [#443]

Tanuka Bhattacharjee, Reshma Kar, Amit Konar, Anna Lekova and Atulya K. Nagar, Jadavpur University, India; Bulgarian Academy of Sciences, Bulgaria; Liverpool Hope University, United Kingdom

P300 is one of the most widely studied event-related potentials. Unfortunately, most of the existing automatic P300 detection schemes

require computations over repetitive trials in both training and recognition phases. Several attempts have recently been endeavored towards the single trial detection of the P300 signals. However, no acceptable solution to the problem is found till date. In the present work, we have attempted to address this problem in the light of latency and (amplitude) deflection of the signal. The intra- and inter-personal variations inherent in these features are managed by the uncertainty management characteristics of General Type-2 Fuzzy Sets. First, these sets are constructed by exploiting the knowledge obtained from different trials of a large number of subjects. The secondary

membership functions of the Type-2 Fuzzy Sets are computed based on a novel density dependent measure of the primary membership functions in the footprint of uncertainty. Second, recognition of P300 in an unknown EEG trial is performed based on the agreement of measured feature values with the General Type-2 Fuzzy knowledge-base. Majority voting of the concerned electrodes makes the scheme more robust. The experimental results show that the proposed algorithm is capable of achieving 88.60% accuracy in single trial detection of P300 instances, which is significantly higher than those obtained in state of the art algorithms.

Applications of Fuzzy Systems in Medicine and Healthcare

Tuesday, July 11, 1:30PM-3:30PM, Room: Sveva, Chair: Susana M. Vieira and Anna Wilbik

1:30PM *Using Fuzzy Logic for Improving Clinical Daily-Care of Beta-Thalassemia Patients* [#246]

Stefania Santini, Pescape' Antonio, Antonio Saverio Valente, Vincenzo Abate, Giovanni Improta, Maria Triassi, Paolo Ricchi and Aldo Filosa, University of Napoli Federico II, Italy; A.O.R.N. Antonio Cardarelli, Italy

The domain of medical decision making process is heavily affected by vagueness and uncertainty issues and - for copying with them - different type of Clinical Decision Support System (CDSS)s, simulating human expert clinician reasoning, have been designed in order to suggest decisions on treatment of patients. In this paper, we exploit fuzzy inference machines to improve the knowledge-based CDSS actually used in the day-by-day clinical care of Beta-thalassemia patients of the Rare Red Blood Cell Disease Unit (RRBCDU) at Cardarelli Hospital (Naples, Italy). All the designed functionalities were iteratively developed on the field, through requirement-adjustment/development/validation cycles executed by an interdisciplinary research team comprising doctors, clinicians and IT engineers. The paper shows exemplary results on the on-line evaluation of Iron Overload during the health status assessment and care management of Beta-Thalassemia patients.

1:45PM *Chattering-free Blood Glucose Level Control Based on ANFIS* [#560]

Roya Ramezanzadeh, Seyed Mahdi Hadad Baygi, Javad Farzaneh and Ali Karsaz, M.Sc. Student, Iran; IEEE Student member, Iran; Assistant Professor, Iran

In the medical field determination of appropriate rate of insulin injection in order to stabilize the blood glucose to a normal level is vital for diabetics. In this paper, an adaptive neuro-fuzzy inference system (ANFIS) based on hybrid blood glucose control data set has been presented. Hybrid blood glucose control employs combination of the fuzzy logic controller optimized by genetic algorithm with well-known Palumbo control method to regulate the blood glucose level in type-1 diabetic mellitus (T1DM) patients. Due to the complexity of the hybrid controller and non-linear and delayed nature of glucose-insulin mechanism as well as chattering phenomenon, the artificial intelligence based technique, especially the ANFIS method, is proposed in this paper. Finally, the simulation results of the fuzzy control, fuzzy-genetic control, Palumbo control and hybrid control are compared to the new proposed ANFIS control, which indicates the proper functioning of the proposed controller for tracking of desired blood glucose level at the lowest possible chattering error.

2:00PM *Short Term Prediction of Low Kidney Function in ICU Patients* [#441]

Ricardo Pacheco, Catia Salgado, Rodrigo Deliberato, Leo Celi and Susana Vieira, IDMEC, Instituto Superior Tecnico, Universidade de Lisboa, Portugal; MIT Critical Data Institute for Medical Engineering and Science, United States

Intensive care treatment presents unique challenges in the medical world. When treating patients, their wide variety leave care providers with few past examples to draw on. Instead of operating in a pure knowledge discovery capacity, decision support systems can be developed to help predict short-term and long-term patient outcome, based upon available data. One area in which generalized severity scoring systems have consistently performed poorly is among patients admitted to the ICU who then develop acute kidney injury. Urine output is used to guide fluid resuscitation and is one of the criteria for the diagnosis of acute kidney injury. This paper provides an example application for predicting short-term critical kidney function in an intensive care unit. Feature construction is performed to extract important aspects of the clinical evolution of the patient. Feature selection is performed on several patient features. Classifiers based on support vector machines and Takagi-Sugeno fuzzy models are developed to predict short term drops in patient urine output rate. Both types of models developed showed comparable results, with an AUC of 78%. This shows potential in using similar classifiers to build an ICU decision support system with the goal of predicting short term complication in the patient and augment current guidelines by anticipating treatment.

2:15PM *Multistage modeling for the classification of numerical and categorical datasets* [#451]

Catia Salgado, Marta Fernandes, Alexandra Horta, Miguel Xavier, Joao Sousa and Susana Vieira, IDMEC, Instituto Superior Tecnico, Universidade de Lisboa, Portugal; Faculdade de Ciencias Medicas, Universidade Nova de Lisboa, Portugal

Logistic regression and Takagi-Sugeno fuzzy models are sequentially trained with categorical and numerical data in an ensemble-based multistage scheme. In the first stage, a logistic regression model is used to transform the binary feature space into a numerical feature that is used to train a second stage of models consisting of an ensemble of two Takagi-Sugeno fuzzy models. In the ensemble, one model is trained in the space of numerical features and stage 1 prediction values. The other model is trained only with samples that were classified with a low degree of confidence by the first stage model, in the space of numerical variables. The final output is given by the average of the ensemble predictions at stage 2. This scheme was devised under the hypothesis that separating binary from numerical features in the modeling process would increase the performance of a single model using both types of features together. The proposed multistage is used to solve a classification problem in a Portuguese hospital. The problem consists of predicting comanagement signalling based on patient clinical data, including diagnosis, procedures, comorbidities and numerical scores, collected before surgery. The multistage performed better in the comanagement dataset, and in 2 out of 5 benchmark datasets.

2:30PM Fuzzy Warning System against Ulnar Nerve Entrapment [#571]

Orcan Alpar and Ondrej Krejcar, University of Hradec Kralove, Czech Republic

Providing sensory innervation, the ulnar nerve runs from the shoulder to the little finger; however, when entrapped in wrist, numbness and decreased sensation would occur. One of the reasons is habitual misuse of computer keyboards in harmful wrist angles, causing constant pressure on the nerve. Therefore in this paper, we present a methodology for identification of the hands including localization of the wrists, supported by a fuzzy warning system. Initially, on the images taken by a camera mounted above a laptop monitor, hands and the left wrist are recognized. Subsequently, angle of the wrist is estimated and the fuzzy warning system is triggered by the angle and the duration, as inputs. While putting forward a new monitoring protocol, a novel application area of fuzzy warning system in preventive medicine is presented to improve the health of individuals and quality of life.

2:45PM NSGA-II based Multi-objective Pollution Routing Problem with Higher Order Uncertainty [#456]

Amit k. Shukla, Rahul Nath and Pranab K. Muhuri, South Asian University, India

Pollution routing problem (PRP) is an NP-hard multi-objective optimization problem. The main goal is pollution reduction and secondary goals are cost/distance minimization, profit maximization etc. We have considered two unique models with two different set of objectives viz. (i) distance and fuel consumption, and (ii) weighted load and fuel consumption. Here, system parameters like demand, driver wages, timing constraints etc. can't be predicted a-priori and involve multiple opinions from the designers. Thus, such uncertain system parameters can be modelled using fuzzy sets. As type-1 fuzzy sets (T1 FSs) has limitations in modelling higher order uncertainty, this paper models these uncertain parameters with interval type-2 fuzzy sets (IT2 FSs). We have solved the problem by an efficient multi-objective evolutionary algorithm viz. NSGA-II (non-dominated sorting genetic algorithm-II). Numerical examples demonstrate the efficiency of the proposed technique over existing (crisp and type-1 fuzzy set based) approaches.

Human Computation for Military Situational Awareness

Tuesday, July 11, 1:30PM-3:30PM, Room: Santa Lucia, Chair: Timothy P. Hanratty Robert J. Hammell II and Nitin Naik

1:30PM Fuzzy-Based Approaches to Human Computation for Military Situational Awareness [#508]

Robert Hammell II and Timothy Hanratty, Towson University, United States; Army Research Laboratory, United States

The objective of this paper is to motivate human computation research, leveraged with the advantages of fuzzy-based systems, within the military situational awareness domain. The goal is to stimulate the use of fuzzy logic's ability for providing more intuitive ways to model complex systems as the basis for research aimed toward facilitating human computation in the context of improving military situational awareness.

1:45PM A Fuzzy-logic Approach to Information Amalgamation [#454]

Timothy Hanratty, Eric Heilman, John Richardson and Justine Caylor, US Army Research Laboratory, United States; Towson University, United States

Current military decision making requires the ability to amalgamate a volume, velocity, variety and veracity of information not seen in most other domains. Confounding the calculation for the value of this information is the realization that seldom does the information agree. Appreciative of these challenges, strides have been made to successfully capture and codify how analysts perceive the value of information (VoI) given its source, content, and latency. Capitalizing on this past success, this paper broadens the scope of VoI research and examines two important and interrelated efforts. Presented first is a novel approach that extends the original VoI calculation from a single element of information to an amalgamation of multiple elements of information that either complement or contradict the original premise. Presented second is a 'human-inside-the-loop' concept designed to assist in scaling future autonomous VoI methodologies - effectively interleaving human and machine computation.

2:00PM Utilizing Human Processing for Fuzzy-Based Military Situation Awareness Based on Social Media [#515]

Sheng Miao and Ziyang Tang, Towson University, United States

With the increasing development of social media, we now face large amounts of up-to-date data, new information resources, and fast and transparent information propagating methods. They have changed the way we understand the world, which means we can have a different perspective when computing situation awareness. In this paper, we give a detailed explanation on how social media data affect situation awareness and our focus is set on the military environment. We discuss why subject matter expert based human computation is necessary and essential for this procedure and how to involve it in the situation awareness architecture. The goal of our paper is to give readers some suggestions on how to use social media and human processing power within the military situational awareness domain.

2:15PM Fuzzy/Human Risk Analysis for Maritime Situational Awareness and Decision Support [#369]

Rafael Falcon, Rami Abielmona, Benjamin Desjardins and Emil Petriu, Larus Technologies Corporation, Canada; University of Ottawa, Canada

Human computation (HC) is an active research field in which people play a notable role as computational elements in an automated system with the aim of arriving at a truly symbiotic human-computer interaction. Situational awareness (SA) and decision support systems (DSSs) are two domains where human computation is rapidly advancing, with the latter arising as an invaluable vehicle to achieve the former. Fuzzy systems and fuzzy logic are two commonly employed tools in these domains due to their inherent capabilities of representing and processing vague and imprecise information while conveying the analysis results in an interpretable fashion. In this paper, we elaborate on the human computation aspects of risk analysis within SA and DSS conducted with the aid of fuzzy sets. The study makes the following contributions: (1) we argue that risk analysis must be a highly automated yet still human-centric endeavour and highlight four manners in which the human component provides value to the underlying data/information fusion processes; (2) we illustrate this fuzzy/human risk analysis methodology through a multimodular Risk Management Framework (RMF) architecture

and its application to the maritime domain, particularly in hard-soft data fusion, automated response generation to maritime incidents, port anomaly filtering and dynamic risk management triggered by contextual knowledge and (3) the framework under discussion can be extrapolated to other domains with negligible effort.

2:30PM *Face Verification using Scale Invariant Feature Transform with Template Security* [#114]

Shubhangi Sapkal, Pukhraj Shrishrimal and Ratnadeep Deshmukh, Government College of Engineering, Aurangabad, India; Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, India

Biometric is a reliable and convenient way for person authentication. Template security is a major concern in practical implementation of biometric system. This work proposes cryptosystem for face verification with fuzzy vault. Here, a secret value is locked using fuzzy vault with a set of points. Fuzzy vault scheme is order invariant and applied for coordinate points, hence SIFT is suitable feature extraction method. SIFT is distinctive invariant feature extraction method. As there is a trade-off between accuracy and security, this is challenge to implement biometric template protection scheme which will not degrade the recognition performance of the biometric system.

2:45PM *Augmented Windows Fuzzy Firewall for Preventing Denial of Service Attack* [#502]

Nitin Naik, Paul Jenkins, Roger Cooke, David Ball, Arthur Foster and Yaochu Jin, Ministry of Defence, United Kingdom; University of Surrey, United Kingdom

The majority of computer systems use security software/hardware to protect against cyber attacks. A firewall is one of the most popular security systems to protect against unauthorized access to or from its hosted network/system. The Microsoft Windows Operating System (OS) is equipped with an intrinsic firewall utility, which has been enhanced over the years to offer advanced security features including IPSec-based virtual private network functionality. This intrinsic Windows Firewall is still not capable of detecting and preventing Denial of Service (DoS) attacks. Nevertheless as an established end user security tool which is supplied with Windows OS, Windows Firewall with some additional intelligence may be an extremely valuable security utility for millions of Windows users. An intelligent Windows fuzzy firewall named FR-WinFirewall has been developed to improve its functionalities and aid prevention of DoS attacks. This paper presents the further extended and generalised version of the FR-WinFirewall to cover IPv6 traffic and for the inclusion of some extra DoS attack types related to ICMPv4, ICMPv6 and TCP. This augmented FR-WinFirewall can monitor, alert and prevent the three types of DoS attacks, ICMP (ICMPv4 and ICMPv6) DoS, UDP DoS and TCP DoS, as these protocols cover the majority of the TCP/IP traffic within any network. In this firewall, three separate fuzzy reasoning components related to three DoS attack types are designed, implemented and tested successfully. The addition of fuzzy intelligence to an intrinsic Windows Firewall makes it comparatively better than many well known firewalls, which are not yet capable of controlling DoS attacks.

Engineering Applications of Fuzzy Sets-II

Tuesday, July 11, 1:30PM-3:30PM, Room: Aragonese, Chair: José Luis Verdegay and David Pelta

1:30PM *Very Short-Term Solar Forecasting Using Fuzzy Time Series* [#551]

Carlos A. Severiano Jr, Petronio C. L. Silva, Hossein Javedani Sadaei and Frederico Gadelha Guimaraes, Universidade Federal de Minas Gerais, Brazil

Solar Photovoltaics is a source of energy very sensitive to climate variations. Therefore, it is very important to apply a forecasting method to a PV system. Solar forecasting provides extremely useful information for tasks such as management of electricity grids and solar energy trading, where good accuracy and good performance are desirable goals for a very short term forecasting model. In this paper, we propose the use of fuzzy time series (FTS) techniques to this problem. Specifically, Chen's first order and high-order FTS methods and the Weighted FTS method are compared with other forecasting models widely used to approach solar irradiance forecasting. We evaluate the performance of FTS methods and different forecasting techniques to solve very short-term solar forecasting problems. The results show that FTS methods are able to achieve significant improvements in forecasting accuracy and performance if compared to other forecasting methods. A discussion on how to improve the forecasting performance of FTS models is also provided.

1:45PM *Interval type-2 fuzzy demand based Vendor Managed Inventory Model* [#566]

Zubair Ashraf, Deepika Malhotra, Pranab K. Muhuri and Q. M. Danish Lohani, South Asian University, India

Vendor managed inventory (VMI) is one of the well-known strategies of merchandizing between suppliers and retailers. The essential aspect in VMI model is to fulfill the demand of the retailers by the suppliers. Since, the costs of items are highly volatile, it is not possible to design a VMI model with deterministic demand. In this paper, we have considered one supplier and

retailer to perform business of multi-product under VMI model with uncertain demand. Thus, it proposes a novel VMI model, termed as 'interval type-2 fuzzy vendor managed inventory (IT2 FVMI) model' that considers interval type-2 fuzzy number to represent the uncertain demand. The objective is to minimize the total cost of VMI by finding the optimum ordered quantity and backordered level. We develop a particle swarm optimization algorithm based solution approach to solve it. A suitable real-world application is considered to perform the simulation. We have considered different number of instances of the products to obtain the results. By comparing the results with the deterministic demand and type-1 fuzzy number, we show the efficacy of our proposed IT2 FVMI model.

2:00PM *A Lab-scale Heliostat Positioning Control using Fuzzy Logic Based Stepper Motor Drive with Micro Step and Multi-Frequency Mode* [#153]

Nirudh Jirasuwankul and Chalermchat Manop, Department of Electrical Engineering, Faculty of Engineering, KMITL, Thailand

This paper proposes positioning control technique for a lab-scale heliostat by application of hybrid stepper motors and fuzzy logic controllers. Steady state tracking error has been kept minimal by micro step drive together with speed control by multi stepping rate adjustment. By supportive video streaming device and image processing, a reflected image of illuminant area on the target is captured and analyzed, an obtaining position error in azimuth and altitude angles are real-time fed to the fuzzy controllers. As a result, the closed loop tracking is formulated and steady state error can then be minimized. Simulation and experimental results confirm the proposed technique.

2:15PM *Selection of an electrification system for an isolated rural area in southern Mexico using Fuzzy AHP-Topsis* [#271]

Veronica Campos-Guzman, M. Socorro Garcia-Cascales, J. Miguel Sanchez-Lozano, David Pelta and M. Teresa Lamata, Depto. Electronica Tecnologia de Computadoras y Proyectos, Spain; Centro Universitario de la Defensa, Spain; Depto Ciencias de la Computacion e Inteligencia Artificial, Spain

At present there are more than 500 thousand houses and 42 thousand classrooms of public schools without electricity in rural and indigenous zones in Mexico. This is because they are not connected to the electricity distribution network, and as a consequence they are the ones most in need of electrification projects. Taking this problem into account, this work models and applies a Fuzzy AHP-TOPSIS multicriteria decision method to select the most appropriate electrification system in a rural area located in the south of Mexico. The AHP method is used to calculate the weights and the TOPSIS method is used to obtain the ranking of the alternatives. To carry out this study, a group of three experts in the Mexican energy field that responded to a survey have been selected. Data were obtained through the corresponding authorities and the families that make up the community. As a result, it was found that a photovoltaic system of 1 kWp isolated was the best alternative to supply electricity to each of the 300 families that make up the community of Cerro Hemoso.

2:30PM *Personalized Route Problem with Fuzzy Constraints* [#282]

Marina Torres, David A. Pelta, Carlos Cruz and Jose L. Verdegay, DECSAI, University of Granada, Spain

The Personalized Route Problem resembles the so-called multi-criteria Shortest Path Problem where every arc (street) of the graph (map) has a set of costs (values) associated to a set of criteria (features). The personalization of the path comes when the user a) determines how important is each criterion according to personal preferences and b) indicates constraints on the criteria values. The preferences are often uncertain, imprecise or inexact. Also, it seems reasonable to allow some relaxation on the constraints. We propose and define a new model for the Personalized Route Problem with fuzzy constraints. As an example, we show its application to the Shortest Path Route with fuzzy constraints on the slopes values.

2:45PM *Criticality Analysis of Purchased Materials Based on Fuzzy Signatures* [#428]

Gabor Farkas, Peter Foldesi and Koczy Laszlo T., Department of Logistics and Forwarding, Szechenyi Istvan University, Hungary

Selecting and evaluating the suppliers represent a very complex task, because a wide range of attributions must be taken into consideration and many of them are difficult to be made objectively quantified. The aim of this research is to provide a new model based on fuzzy signatures for selecting and evaluating the critical parts for the production.

Applications of aggregation functions II

Tuesday, July 11, 1:30PM-3:30PM, Room: Catalana, Chair: Radko Mesiar, Javier Montero, Irina Perfilieva Humberto Bustince

1:30PM *Reliability-guided Fuzzy Classifier Ensemble* [#54]

Tianhua Chen, Pan Su, Changjing Shang and Qiang Shen, Department of Computer Science, Aberystwyth University, Aberystwyth, UK, United Kingdom; School of Control and Computer Engineering, North China Electric Power University, Baoding, China, China

Classifier ensembles form an important approach to improving classification performance. As such, there have been different proposals made in the literature that provide a range of means to construct and aggregate classifier ensembles. However, the resulting systems may contain unreliable members with false or biased judgements in the ensemble. The removal of unreliable members is necessary to optimise the overall performance of such systems. Smaller ensembles involving reduced ensemble members also helps relax the requirement of computational memory, thereby strengthening the system's run-time efficiency. To differentiate the potential contributions of different ensemble members while reducing the adverse impact of any unreliable judgement upon the system, a nearest neighbour-based reliability measure is incorporated into the process of classifier ensemble selection. In particular, reliabilities of selected ensemble members are perceived as a stress function, from which argument-dependent weights are heuristically generated for final aggregated decision. Experimental investigations are carried out, demonstrating the efficacy of the proposed approach, where fuzzy classifiers are utilised as base members of the emerging ensemble.

1:45PM *Selection of alternatives in decision making problem with uncertainty information by generalized reciprocity* [#177]

Barbara Pekala, University of Rzeszow, Poland

In this paper interval-valued fuzzy relations are studied. The problem of selection of alternatives in decision making is examined. In particular, a new definition of transitivity based on the measure of the intensity preference

between pairs of alternatives is presented and its apply to solve decision making problem is proposed.

2:00PM *Trend-cycle Forecasting Based on New Fuzzy Techniques* [#192]

Linh Nguyen and Vilem Novak, Institute for Research and Applications of Fuzzy Modelling, NSC IT4Innovations, University of Ostrava 30. dubna 22, 701 03 Ostrava 1, Czech Republic, Czech Republic

This contribution is devoted to a method for forecasting of the trend-cycle of time series based on the application of a combination of the higher degree fuzzy transform and fuzzy natural logic (FNL) techniques. The main idea is to predict future components of the direct fuzzy transform of a time series. The forecast trend-cycle is then computed using the inverse fuzzy transform applied to the predicted components.

2:15PM *B-properties of fuzzy relations in aggregation process - the "converse problem"* [#287]

Urszula Bentkowska, University of Rzeszow, Poland

In this paper the problem of connections between input fuzzy relations R_1, \dots, R_n on a set X and the output fuzzy relation $RF = F(R_1, \dots, R_n)$ on X is studied, where F is a function on the unit interval $[0, 1]$ and RF is an aggregated fuzzy relation. Namely, fuzzy relation $RF = F(R_1, \dots, R_n)$ is assumed to have a given property and the properties of fuzzy relations R_1, \dots, R_n are examined. This approach to checking connections between input fuzzy relations and the output fuzzy relation is a new one. In the literature the problem of preservation, by an aggregation function F , diverse types of properties of fuzzy relations R_1, \dots, R_n is examined. The properties, which are examined in this paper, depend on their notions on binary operations B on the unit interval $[0, 1]$, i.e. they are generalized versions of known properties of fuzzy relations.

2:30PM Binary Aggregation Functions in Software Plagiarism Detection [#296]

Maciej Bartoszuk and Marek Gagolewski, Faculty of Mathematics and Information Science, Warsaw University of Technology, Poland; Systems Research Institute, Polish Academy of Sciences, Poland

Supervised learning is of key interest in data science. Even though there exist many approaches to solving, among others, classification as well as ordinal and standard regression tasks, most of them output models that do not possess useful formal properties, like nondecreasingness in each independent variable, idempotence, symmetry, etc. This makes them difficult to interpret and analyze. For instance, it might be impossible to determine the importances of individual features or to assess the effects of increasing the values of predictors on the behavior of a chosen response variable. Such properties are especially important in software plagiarism detection, where we are faced with the combination of degrees to which how much a code chunk A is similar to (or contained in) B as well as how much B is similar to A. Therefore, in this paper we consider a new method for fitting B-spline tensor

product-based aggregation functions to empirical data. An empirical study indicates a highly competitive performance of the resulting models. Additionally, they possess an intuitive interpretation which is highly desirable for end-users.

2:45PM OWA-based Linkage and the Genie Correction for Hierarchical Clustering [#432]

Anna Cena and Marek Gagolewski, Systems Research Institute, Polish Academy of Sciences, Poland

In this paper we thoroughly investigate various OWA-based linkages in hierarchical clustering on numerous benchmark data sets. The inspected setting generalizes the well-known single, complete, and average linkage schemes, among others. The incorporation of weights into the cluster merge procedure creates an opportunity to make use of experts' knowledge about a particular data domain so as to generate partitions of a given data set that better reflect the true underlying cluster structure. Moreover, we introduce a correction for the inequality of cluster size distribution - similar to the one proposed in our recently introduced Genie algorithm - which results in a significant performance boost in terms of clustering quality.

Matrix Factorization for Fuzzy Clustering and Related Topics

Tuesday, July 11, 1:30PM-3:30PM, Room: Giardino, Chair: Abdul Suleman Boris Mirkin

1:30PM Validation of Archetypal Analysis [#21]

Abdul Suleman, Instituto Universitario de Lisboa (ISCTE-IUL), Portugal

We use an information-theoretic criterion to assess the goodness-of-fit of the output of archetypal analysis (AA), also intended as a fuzzy clustering tool. It is an adaptation of an existing AIC-like measure to the specifics of AA. We test its effectiveness using artificial data and some data sets arising from real life problems. In most cases, the results achieved are similar to those provided by an external similarity index. The average reconstruction accuracy is about 93%.

1:45PM Sequential Possibilistic One-Means Clustering [#60]

Thomas Runkler and James Keller, Siemens AG, Germany; University of Missouri-Columbia, United States

Fuzzy c-means (FCM) clustering is known to be sensitive to outliers and noise. Possibilistic c-means (PCM) has been reported to be more robust against outliers and noise but may yield coincident clusters. We introduce a variant of PCM called sequential possibilistic one-means (SP1M) that finds clusters sequentially, takes into account the previously found clusters for initialization, and discards coincident clusters. Experiments with the well-known BIRCH benchmark data set and two variants of BIRCH indicate that SP1M is able to find a significantly larger percentage of the clusters contained in the data, with about twice as many cluster update steps, but significantly faster than FCM and PCM.

2:00PM Ideal Type Model and Associated Method for Relational Fuzzy Clustering [#142]

Susana Nascimento and Boris Mirkin, Faculty of Science and Technology, Universidade Nova de Lisboa, Portugal; National Research University, Higher School of Economics, Russian Federation

The ideal type model by Mirkin and Satarov (1990) expresses data points as convex combinations of some 'ideal type' points. However, this model cannot prevent the ideal type points being far away from the observations and, in fact, requires that. Archetypal analysis by Cutler and Breiman (1994) and proportional membership fuzzy clustering by Nascimento et al. (2003) propose different ways of avoiding this entrapment. We propose one more way out -- by assuming the ideal types being mutually orthogonal and transforming the model by multiplying it over its transpose. The obtained additive fuzzy clustering model for relational data is akin to that more recently analysed by Mirkin and Nascimento (2012) in a different context. The one-by-one clustering approach to the ideal type model is reformulated here as that naturally leading to a spectral clustering algorithm for finding fuzzy membership vectors. The algorithm is proven to be computationally valid and competitive against popular relational fuzzy clustering algorithms.

2:15PM Fuzzy Clustering of Multi-View Relational Data with Pairwise Constraints [#225]

Diogo Branco and Francisco de Carvalho, Universidade Federal de Pernambuco-UFPE / Centro de Informatica-CIn, Brazil

This paper presents SS-MVFCVSMdd, a semi-supervised multiview fuzzy clustering algorithm for relational data described by multiple dissimilarity matrices. SS-MVFCVSMdd provides a fuzzy partition in a predetermined number of fuzzy clusters, a representative for each fuzzy cluster, learns a relevance weight for each dissimilarity matrix, and takes into account pairwise constraints must-link and cannot-link, by optimizing a suitable objective function. Experiments with multi-view real-valued data sets described by multiple dissimilarity matrices show the usefulness of the proposed algorithm.

Fuzzy Natural Language Processing II

Tuesday, July 11, 1:30PM-3:30PM, Room: Borbonica, Chair: Joao Paulo Carvalho Keeley Crockett

1:30PM *Combining Ratings and Item Descriptions in Recommendation Systems using Fuzzy Fingerprints* [#342]

Andre Carvalho, Pavel Calado and Joao Paulo Carvalho, INESC-ID / Instituto Superior Tecnico, Universidade de Lisboa, Portugal

Memory-based Collaborative filtering solutions are dominant in the Recommendation Systems domain, due to their low implementation effort and service maintenance, when compared to Model-based approaches. Memory-based systems often rely on similarity metrics to compute similarities between items (or users) using ratings, in what is often named neighbor-based Collaborative filtering. This paper applies Fuzzy Fingerprints to create a novel similarity metric. In it, the Fuzzy Fingerprint of each item is described with a ranking of users ratings, combined with words obtained from the items' description. This allows the presented similarity metric to use fewer neighbors than other well-known metrics such as Cosine similarity or Pearson Correlation. Our proposal is able to reduce RMSE by at least 0.030 and improve NDCG10 by at least 0.017 when compared with the best baseline here presented.

1:45PM *Fuzzy Hamming distinguishability* [#86]

Laura Franzoi and Andrea Sgarro, Faculty of Mathematics and Computer Science - University of Bucharest, Romania; Department of Mathematics and Geosciences - University of Trieste, Italy

Back in 1967 the Croat linguist Z. Muljajic had used a fuzzy generalization of the Hamming distance between binary strings to classify Romance languages. In 1956 Cl. Shannon had introduced the notion of codeword distinguishability in zero-error information theory. Distance and distinguishability are subtly different notions, even if, with distances as those usually met in coding theory (ruling out zero-error information theory, which is definitely non-metric), the need for string distinguishabilities evaporates, since the distinguishability turns out to be an obvious and trivial function of the distance. Fuzzy Hamming distinguishabilities derived from Muljajic distances, instead, are quite relevant and must be considered explicitly. They are very easy to compute, however, and we show how they could be applied in coding theory to channels with erasures and blurs. Fuzzy Hamming distinguishabilities appear to be quite a promising tool to extend Muljajic approach from linguistic classification to linguistic evolution.

2:00PM *Deictic Gesture Enhanced Fuzzy Spatial Relation Grounding in Natural Language* [#405]

Arjuna Srimal, Viraj Muthugala and Buddhika Jayasekara, University of Moratuwa, Sri Lanka

In the recent past, domestic service robots have come under close scrutiny among researchers. When collaborating with humans, robots should be able to clearly understand the instructions conveyed by the human users. Voice interfaces are frequently used as a mean of interaction interface between users and robots, as it requires minimum amount of work overhead from the users. However, the information conveyed through the voice instructions are often ambiguous and cumbersome due to the inclusion of imprecise information. The voice instructions are often accompanied with gestures especially when referring objects, locations, directions etc. in the environment. However, the information conveyed solely through these gestures is also imprecise. Therefore, it is more effective to consider a multimodal interface rather than a unimodal interface in order to understand the user instructions. Moreover, the information conveyed through the gestures can be used to improve the understanding of the user instructions related to object placements. This paper proposes a method to enhance the interpretation of user instructions related to the object placements by interpreting the information conveyed through voice and gestures. Furthermore, the proposed system is capable of adapting the understanding, according to the spatial arrangement of the workspace of the robot. Fuzzy logic system is proposed in order to evaluate the information conveyed through these two modalities while considering the arrangement of the workspace. Experiments have been carried out in order to evaluate the

performance of the proposed system. The experimental results validate the performance gain of the proposed multimodal system over the unimodal systems.

2:15PM *Learning to Rank Answers to Closed-Domain Questions by Using Fuzzy Logic* [#574]

Marco Pota, Massimo Esposito and Giuseppe De Pietro, Institute for High Performance Computing and Networking (ICAR-CNR), Italy

Question answering (QA) is a challenging task and has received considerable attention in the last years. Answer selection among candidate answers is one of the main phases for QA and the best answer to be returned is determined in this phase. A common approach consists in considering the selection of the final answer(s) as a ranking problem. So far, different methods have been proposed, mainly oriented to produce a single best ranking model operating in the same way on all the question types. Differently, this paper proposes a fuzzy approach for ranking and selecting the correct answer among a list of candidates in a state-of-the-art QA system operating with factoid and description questions on Italian corpora pertaining a closed domain. Starting from the consideration that this ranking problem can be reduced to a classification one, the proposed approach is based on the Likelihood-Fuzzy Analysis (LFA), applied in this case for mining fuzzy rule-based models able to discern correct (True) from incorrect answers (False). Such fuzzy models are mined as specifically tailored to each question type, and, thus, can be individually applied to produce a more robust and accurate final ranking. An experimental session over a collection of questions pertaining the Cultural Heritage domain, using a manually annotated gold-standard dataset, shows that considering specific fuzzy ranking models for each question type improves the accuracy of the best answer returned back to the user.

2:30PM *Fuzzy Logic in Natural Language Processing* [#49]

Vilem Novak, University of Ostrava, IRAFM, Czech Republic

One of the proclaims often emphasized in papers on fuzzy sets and fuzzy logic is their ability to model semantics of certain linguistic expressions because their inherent vagueness can be captured by fuzzy sets. This direction of research was initiated by L. A. Zadeh already in his early papers and since then, most of the applications of fuzzy sets emphasize presence of natural language, at least in hidden form. Still, this ability is not generally accepted by linguists. In this paper we try to show that capturing linguistic semantics requires more sophisticated models. One possibility has been elaborated in the concept of 'emph{fuzzy natural logic}' (FNL) that is a mathematical theory whose roots lay in the concept of natural logic developed by linguists and logicians. We also argue that it is reasonable to develop a simplified model that would capture the main features of the semantics of natural language and thus make it possible to realize sophisticated technical applications. In the paper, we outline how model of the meaning of basic constituents of natural language (nouns, adjectives, adverbs, verbs) has been elaborated in FNL.

2:45PM *Fuzziness and Variability in Natural Language Processing* [#490]

Adria Torrens Urrutia, Maria Dolores Jimenez Lopez and Philippe Blache, Universitat Rovira i Virgili, Spain; Laboratoire Parole et Langage, France

This paper aims to establish a link between linguistics and fuzzy phenomena. Throughout the history, linguistics has been relying on discrete descriptions to explain Natural Language Processing. This fact has a negative impact in various areas of language and technology since linguistics rejects all the inputs which are out from a discrete rule. Although this paper might approach the subject more from a linguistic than from a mathematical point of view, we present the theoretical considerations and reasoning used in elaborating a formal characterization of fuzziness in natural language grammars. Property Grammars will be used as the formal theory in order to explain Natural Language fuzziness and variability.

Data Streams and Evolving Fuzzy Systems

Tuesday, July 11, 1:30PM-3:30PM, Room: Auditorium, Chair: Jie Lu, Edwin Lughofer, Igor Skrjanc Plamen Angelov

1:30PM *Cloud-Based Evolving Intelligent Method for Weather Time Series Prediction* [#228]

Eduardo Soares, Vania Mota, Ricardo Poucas and Daniel Leite, Federal University of Lavras, Brazil

This paper concerns the application of a cloud-based intelligent evolving method, namely, a typicality-and eccentricity-based method for data analysis (TEDA), to predict monthly mean temperature in different cities of Brazil. Past values of maximum, minimum and mean monthly temperature, as well as previous values of exogenous variables such as cloudiness, rainfall and humidity were considered in the analysis. A non-parametric Spearman correlation based method is proposed to rank and select the most relevant features and time delays for a more accurate prediction. The datasets were obtained from weather stations located in main cities such as Sao Paulo, Manaus, and Porto Alegre. These cities are known to have particular weather characteristics. TEDA prediction results are compared with results provided by the evolving Takagi-Sugeno (eTS) and the extended Takagi-Sugeno (xTS) methods. In general, TEDA provided slightly more accurate predictions at the price of a higher computational cost.

1:45PM *Learning evolving Mamdani fuzzy systems based on parameter optimization* [#350]

Dongjiao Ge and Xiao-Jun Zeng, School of Computer Science, University of Manchester, United Kingdom

Evolving fuzzy systems are widely recognized to be able to capture the non-stationary phenomenon of data stream. Most existing algorithms for the parameter identification problem of evolving fuzzy systems are built on heuristic methods rather than the optimal method, when there is a structure change of the system such as rule adding, merging or removing. In order to address this issue, this paper proposes a new online learning algorithm with time varying structure and parameters from a parameter optimization point of view, in which the influence between fuzzy rules is naturally considered, to identify evolving Mamdani fuzzy systems. Firstly, to minimize the local error function and get the accurate (rather than heuristic) weighted recursive least square estimation of the consequent parameters, the methods for structure changing and parameter updating are obtained. Further, these methods are proved leading to a new effective algorithm for optimum solutions. Moreover, for the proposed online learning approach, a special type of weighted recursive least square updating formulas of the consequent parameters are proposed. Numerical experiments and comparisons with other state-of-art algorithms demonstrate that the proposed algorithm can achieve better predictions than other algorithms judged by accuracy.

2:00PM *FuzzStream: Fuzzy Data Stream Clustering Based on the Online-Offline Framework* [#498]

Priscilla de Abreu Lopes and Heloisa de Arruda Camargo, Universidade Federal de Sao Carlos, Brazil

Systems capable of generating data quickly and continuously, known as Data Streams, are a reality today and tend to increase. Due to the nature of Data Streams, unsupervised learning, such as clustering algorithms, is appropriate. In addition, techniques derived from fuzzy set theory can be useful and add flexibility to the process. Fuzzy clustering algorithms for Data Streams found in the literature are based on chunks, which require the definition of several parameters besides presenting the drawback of overly reducing the summarization of data. An approach to Data Stream clustering that overpasses some of the limitations of chunk-based algorithms is the one called Online-Offline Framework. This framework comprises two phases: summarization and clustering. To the best of our knowledge, there is not a fuzzy version of this framework. The objective of this work is to propose a fuzzy version of Online-Offline Framework, called FuzzStream, whose main component is a summarization structure and its corresponding maintenance algorithm to be used in the online phase. The well known Weighted Fuzzy

C-Means clustering algorithm is used in the offline phase. Experiments show that our proposal is a promising approach to deal with data streams and presents benefits with relation to the classic version.

2:15PM *Investigating live streaming data for student behaviour modelling* [#110]

Jie Yang, Jun Ma and Sarah Howard, University of Wollongong, Australia

Modelling technology integration in the teaching and learning environment is a complex, uncertain and dynamic practice. A large amount of student behaviour data has been gathered literately for different processing purposes. Yet, considerable questions are still remaining due to the huge data volume, diversification and uncertainty. In this work, we implement a big-data analytical framework for online behaviour modelling, particularly taking streaming data of students' online activity from their laptop usage as an illustrative example. The proposed framework covers details from accessing streaming records to storing heterogeneous data. Furthermore, the work also demonstrates the use of a TF-IDF based feature generation and fuzzy representation strategy to discover critical patterns via this behaviour data. The accuracy of the modelling work is evaluated using students' score on a national-wide test. Experimental results show that the employed TF-IDF feature is much stabler than other traditional features, thereby achieving a better modelling performance. In summary, the simulation result demonstrates the flexibility and applicability of the proposed framework for processing complex behaviour data, and revealing important patterns for decision making.

2:30PM *A Fuzzy Kernel c-Means Clustering Model for Handling Concept Drift in Regression* [#205]

Yiliao Song, Guangquan Zhang, Jie Lu and Haiyan Lu, University of Technology, Sydney, Australia

Concept drift, given the huge volume of high-speed data streams, requires traditional machine learning models to be self-adaptive. Techniques to handle drift are especially needed in regression cases for a wide range of applications in the real world. There is, however, a shortage of research on drift adaptation for regression cases in the literature. One of the main obstacles to further research is the resulting model complexity when regression methods and drift handling techniques are combined. This paper proposes a self-adaptive algorithm, based on a fuzzy kernel c-means clustering approach and a lazy learning algorithm, called FKLL, to handle drift in regression learning. Using FKLL, drift adaptation first updates the learning set using lazy learning, then fuzzy kernel c-means clustering is used to determine the most relevant learning set. Experiments show that the FKLL algorithm is better able to respond to drift as soon as the learning sets are updated, and is also suitable for dealing with reoccurring drift, when compared to the original lazy learning algorithm and other state-of-the-art regression methods.

2:45PM *Fuzzy Time Windowing for Gradual Concept Drift Adaptation* [#321]

Anjin Liu, Guangquan Zhang and Jie Lu, CAI, FEIT, University of Thecnology Sydney, Australia

The aim of machine learning is to find hidden insights into historical data, and then apply them to forecast the future data or trends. Machine learning algorithms optimize learning models for lowest error rate based on the assumption that the historical data and the data to be predicted conform to the same knowledge pattern (data distribution). However, if the historical data is not enough, or the knowledge pattern keeps changing (data uncertainty), this assumption will become invalid. In data stream mining, this phenomenon of knowledge pattern changing is called concept drift. To address this issue, we propose a novel fuzzy windowing concept drift adaptation (FW-DA)

method. Compared to conventional windowing-based drift adaptation algorithms, FW-DA achieves higher accuracy by allowing the sliding windows to keep an overlapping period so that the data instances belonging to different concepts can be determined more precisely. In addition, FW-DA statistically guarantees that the upcoming data conforms to the inferred

knowledge pattern with a certain confidence level. To evaluate FW-DA, four experiments were conducted using both synthetic and real-world data sets. The experiment results show that FW-DA outperforms the other windowing-based methods including state-of-the-art drift adaptation methods.

Tuesday, July 11, 4:00PM-6:00PM

Type-2 Fuzzy Sets and Systems Applications-II

Tuesday, July 11, 4:00PM-6:00PM, Room: Normanna, Chair: Christian Wagner and Jon Garibaldi

4:00PM *Hierarchical interval type-2 beta fuzzy knowledge representation system for path preference planning* [#476]

Mariam Zouari, Nesrine Baklouti, Habib Kammoun, Javier Sanchez-Medina, Mounir Ben Ayed and M. Adel Alimi, ENIS-REGIMLAB, Tunisia; University of Las Palmas de Gran Canaria, Spain

Traffic congestion leads to many problems, namely road users' dissatisfaction, air pollution and waste of time and fuel. For this reason, congestion detection at an early stage is required to perform an efficient exploitation of resources. This paper proposed a Hierarchical Type-2 Beta Fuzzy Knowledge Representation system for the selection of optimal route. Consequently, this system aims to avoid longer travel times, and to decrease traffic accidents and the number of traffic congestion situations. The selection is performed through itineraries assessment by contextual factors such as Max speed and density of a given path. For the validation, the traffic simulation was done with the open source microscopic road traffic simulator SUMO. When compared with the Dijkstra's algorithm, the proposed system showed better performance in terms of average travel time and path flow. These promising results prove the potential of our method to relieve traffic congestion.

4:15PM *Computing Derivatives in Interval Type-2 Fuzzy Logic Systems Trained by Steepest Descent Method for Fault Classification in a Switch Machine* [#15]

Eduardo Aguiar, Renan Amaral, Marley Vellasco and Moises Ribeiro, Federal University of Juiz de Fora, Brazil; Pontifical Catholic University of Rio de Janeiro, Brazil

A switch machine is an electromechanical device that allows railway trains to be guided from one track to another. Among all possible faults that can occur in a switch machine, the three main ones are: lack of lubrication, lack of adjustment and malfunction of a component. Aiming to classify these faults, an important contribution of this work is to address the height type-reduction and interval singleton type-2 fuzzy logic system derivatives. The computational simulations are performed with real data set provided by a Brazilian company of the railway sector. The obtained results are compared with other models reported in the literature (Bayes theory, multilayer perceptron neural network and type-1 fuzzy logic system), demonstrating the effectiveness of the proposed classifier and revealing that the proposal is able to properly handle with uncertainties associated with the measurements and with the data that are used to tune the parameters of the model. In addition, the convergence speed and performance analysis show that the proposed interval singleton type-2 fuzzy logic system is attractive for classifying faults in a switch machine.

4:30PM *Time Series Forecasting with Interval Type-2 Intuitionistic Fuzzy Logic Systems* [#127]

Imo Eyoh, Robert John and Geert De Maere, University of Nottingham, United Kingdom

Conventional fuzzy time series approaches make use of type-1 or type-2 fuzzy models. Type-1 models with one index (membership grade) cannot fully handle the level of uncertainty inherent in many real world applications. The type-2 models with upper and lower membership functions do handle uncertainties in many applications better than its type-1 counterparts. This study proposes the use of interval type-2 intuitionistic fuzzy logic system of Takagi-Sugeno-Kang (IT2IFLS-TSK) fuzzy inference that utilises more parameters than type-2 fuzzy models in time series forecasting. The IT2IFLS utilises more indexes namely upper and lower non-membership functions. These additional parameters of IT2IFLS serve to refine the fuzzy relationships obtained from type-2 fuzzy models and ultimately improve the forecasting performance. Evaluation is made on the proposed system using three real world benchmark time series problems namely: Santa Fe, tree ring and Canadian lynx datasets. The empirical analyses show improvements of prediction of IT2IFLS over other approaches on these datasets.

4:45PM *Accuracy Evaluation of Soft Classifiers using Interval Type-2 Fuzzy Sets Framework* [#78]

Elisabetta Binaghi, Alberto Vergani and Valentina Pedoia, University of Insubria, Italy; UCSF School of Medicine, United States

This paper proposes a new accuracy evaluation method within a behavioral comparison strategy which uses interval type-2 fuzzy sets and derived operations to model reference data and define soft accuracy indexes. The method addresses the case in which grades of membership, collected by surveying experts, will often be different for the same reference pattern, because the experts will not necessarily be in agreement. The approach is illustrated using simple examples and an application in the domain of biomedical image segmentation.

5:00PM *Genetic Algorithm-Based Interval Type-2 Fuzzy Model Identification for People with Type-1 Diabetes* [#75]

Tsung-Chih Lin, Yi-Jie Huang, Josephine I-Ju Lin, E. Balas Valentina and Seshadhri Srinivasan, Feng-Chia University, Taiwan; Chung Yuan Christian University, Taiwan; Aurel Vlaicu University, Romania; Department of Engineering, University of Sannio, Italy

In this paper, the glucose regulation system is identified by interval type-2 fuzzy neural network based on genetic algorithm used to adapt the model parameters. The interval type-2 fuzzy neural network is constructed to identify the glucose regulation system of the people with diabetes type-1. The centers and widths of the memberships and output weights of the interval type-2 fuzzy neural network can be tuned by optimizing genetic algorithm. The simulation result shows that the glucose-insulin behavior can be well identified by the advocated identification scheme

5:15PM *Control of a Flexible Air-breathing Hypersonic Vehicle with Measurement Noises Using Adaptive Interval Type-2 Fuzzy Logic System* [#226]
Xinlong Tao, Jianqiang Yi, Ruyi Yuan and Zhen Liu,
Institute of Automation, Chinese Academy of Sciences;
University of Chinese Academy of Sciences, China

In this paper, a novel control scheme for the flexible air-breathing hypersonic vehicle (FAHV) using adaptive interval type-2 fuzzy logic system (AIT2-FLS) is proposed to reduce the side effects of measurement noises in the velocity

channel and altitude channel as well as flexible dynamics in real applications. After input-output linearization of the longitudinal model of FAHV, the dynamic inversion controller is formulated to track the reference commands based on state feedback. The AIT2-FLS is further developed to deal with the model uncertainties and input errors. Besides, the state estimator is applied to estimate the true values of the corrupted outputs. The stability characteristics of both the controller and the state estimator are analyzed. The whole control scheme is finally obtained through combining the controller and the state estimator based on the separation principle. Simulation results demonstrate the robustness of our proposed control scheme against measurement noises and flexibilities.

Fuzziness in knowledge-based engineering systems

Tuesday, July 11, 4:00PM-6:00PM, Room: Sveva, Chair: Hajer Baazaoui Zghal Adel Alimi and Umberto Straccia

4:00PM *Hypergraph Fuzzy Minimals Transversals Mining : A New Approach For Social Media Recommendation* [#408]

Hazem Souid, Chiraz Trabelsi, Gabriella Pasi and Sadok Ben Yahia, University of Tunis El Manar, Tunisia; Universita degli Studi di Milano-Bicocca, Italy

User preference discovery aims to detect the patterns of user preferences for various topics of interest or items such as movie genre or category. Preferences discovery is a crucial stage in the development of intelligent personalization systems. Although a variety of studies have been proposed in the literature addressing a wide range of applications such as recommender systems or personalized search, only a few of them have considered the management of imprecision in the representation of user and item features. This paper aims to address the above issue by using fuzzy sets. The paper proposes a general framework for preferences discovery through fuzzy sets and fuzzy models and it introduces a new algorithm for representing and discovering fuzzy user interest profile. Based on the results of the empirical evaluation, the proposed approach outperforms two well-known recommendation approaches in terms of well-known quality assessment metrics, namely: discounted cumulative gain, precision, recall, as well as F1-measure.

4:15PM *Generalized Fuzzy Soft Set Based Fusion Strategy for Activity Classification in Smart Home* [#251]

Sofiane Bouznad, Faouzi Sebbak, Yacine Amirat, Abdelghani Chibani and Farid Benhammedi, LISSI Laboratory, UPEC, France; Ecole Militaire Polytechnique (EMP), Algeria

In recent years, a plethora of different studies for design of traditional ensemble classifiers has been proposed in order to improve final recognition accuracy. However, among the ensemble classifiers, combination methods are focused on building independent classifiers of the same or different algorithms using majority voting methods. In this paper, we present a new fusion scheme for ensemble classifiers based on a new concept called Generalized Fuzzy Soft Set (GFSS), which we apply in activity classification. Essentially, we apply a weighted aggregate operator to the output of each classifier in order to fuse the GFSS into a more reliable classifier. The proposed fusion method is based on a new ranking algorithm to classify activities. We show that the proposed method produces more accurate results than the best single classifier and its effectiveness is demonstrated by comparing it with single classifier in terms of activity recognition accuracy.

4:30PM *Fuzzy Detectabilities for Fuzzy Discrete Event Systems* [#83]

Ahmed Mekki, Feng Lin, Hao Ying and Michael Simoff, Wayne State University, United States; Henry Ford Health System, United States

Fuzzy discrete event systems are useful models for solving complex practical problems in biomedical and other fields. The theory of detectabilities in conventional crisp discrete event systems investigates state determination or estimation based on event observation. The theory is also important to fuzzy discrete event systems (e.g., disease diagnosis and treatment effectiveness evaluation). In this paper, we investigate fuzzy detectabilities for fuzzy discrete event systems. We first introduce fuzzy discrete event systems with constraints, which provide a new and more realistic model for complex systems. We also extend detectabilities of crisp discrete event systems to N-detectabilities and prove the relation between detectabilities and N-detectabilities. We then define fuzzy N-detectabilities and develop an algorithm to check fuzzy N-detectabilities of a fuzzy discrete event system. The computational complexity of the algorithm is analyzed. To model a fuzzy discrete event systems with constraints, we propose to use a (crisp) automaton to model the constraints in addition to a fuzzy automaton. This new model significantly enhances the modeling power of fuzzy discrete event systems and contains the previous model as a special case. In biomedical applications such as disease diagnosis and treatment, it is often important to know a patient's condition. Therefore, state estimation and detectabilities are important in such applications and we need to investigate fuzzy detectabilities of fuzzy discrete event systems.

4:45PM *Neutrosophic Recommender System for Medical Diagnosis Based on Algebraic Similarity Measure and Clustering* [#23]

Thanh Nguyen Dang, Son Le Hoang and Ali Mumtaz, People's Police University of Technology and Logistics, Bac Ninh, Vietnam, Viet Nam; Vietnam National University, Viet Nam; University of Southern Queensland, 4300, Australia, Australia

In this paper, we propose a neutrosophic recommender system for medical diagnosis using both neutrosophic similarity measure and neutrosophic clustering to capture the treatment of similar patients at a different levels within a concurrent group. The proposed algorithm allows similar patients being treated concurrently in a group. Firstly, the similarities are measured based on the algebraic operations and their theoretic properties. Secondly, a clustering algorithm is used to identify neighbors that are in the same cluster and share common characteristics. Then, a prediction formula using results of both the clustering algorithm and the similarity measures is designed. Experiment indicates the advantages and superiority of the proposal.

5:00PM *On the Generalization of the Discovery of Subsumption Relationships to the Fuzzy Case* [#449]

Fernando Bobillo, Carlos Bobed and Eduardo Mena,
University of Zaragoza, Spain

Many real-world applications require ontology alignment to integrate semantic information from different sources. However, most of the work in the field is restricted to finding synonymy relationships, and hyponymy relationships have not received similar attention. In this paper, we discuss some extensions of our previous work in the discovery of subsumption relationships with fuzzy clustering, aggregation operators, Formal Concept Analysis, and synonymy relationships.

5:15PM *A Beta-Fuzzy-Near-Sets approach to research for visually similar content images* [#487]

Yosr Ghozzi, Nesrine Baklouti and M. Adel Alimi,
REGIM, Tunisia

In the automated search system, similarity is a key concept for solving the human task. The human process is a natural categorization, which underlies many natural abilities such as image recovery, language comprehension, decision making or pattern recognition. In this paper, the focus is on the use of similarities in image retrieval search using near sets of similarity approaches. The results showed that a general framework for Near set is compatible with these foundations, and that similarity measurements can be involved in all steps of the image research process. We therefore focus on the fuzzy logic which provides interesting tools for data mining mainly because of its ability to represent imperfect information. We then introduce a new category of a fuzzy set : the Beta function. We finally illustrate our work with examples of similarities used in the real world of image retrieval problems.

Fuzzy Set Approaches to Geosciences

Tuesday, July 11, 4:00PM-6:00PM, Room: Santa Lucia, Chair: Long Thanh Ngo and Witold Pedrycz

4:00PM *Fuzzy Inference on Fuzzy Spatial Objects (FIFUS) for Spatial Decision Support Systems* [#513]

Anderson Chaves Carniel and Markus Schneider,
University of Sao Paulo, Brazil; University of Florida,
United States

Spatial Decision Support Systems have received increasing interest in geographical, political, and economical applications such as agricultural cultivation, disaster management, and industrial settlement. For instance, farmers want to know what the best farmland areas are to grow a specific crop, political decision makers want to know what the areas are that should be protected based on risk zones, and companies would like to know the best location to place a new production facility. In many cases, the spatial phenomena of interest have a vague and imprecise extent and can be adequately represented by fuzzy spatial objects such as fuzzy regions. In this paper, we formally propose a general-purpose model named Fuzzy Inference on Fuzzy Spatial Objects (FIFUS) that incorporates fuzzy spatial objects into its inference strategy and supplies the user with recommendations, estimations, and predictions based on fuzzy inference rules and expert knowledge.

4:15PM *Feature-Reduction Fuzzy Co-Clustering algorithm for hyperspectral image segmentation* [#421]

Van Nha Pham, Long Thanh Ngo and Duc Thao
Nguyen, Le Quy Don Technical University, Viet Nam;
MIST Institute of Science and Technology, Viet Nam

The fuzzy co-clustering algorithms are considered as effective technique for clustering the complex data, such as high-dimensional and large size. In general, features of data objects are considered the same importance. However, in reality, the features have different roles in data analyses; even some of them are considered redundancy in the individual case for data sets. Removing these features is a way for the dimensionality reduction, which needs to improve the performance of data processing algorithms. In this paper, we proposed an improved fuzzy co-clustering algorithm called feature-reduction fuzzy co-clustering (FRFCoC), which can automatically calculate the weight of features and put them out of the data processing. We considered the objective function of the FCoC algorithm with feature-weighted entropy and build a learning procedure for components of the objective function, then reducing the dimension of data by eliminating irrelevant features with small weights. Experiments were conducted on synthetic data sets and hyperspectral image using the robust assessment indexes. Experimental results demonstrated the proposed algorithm outperformed the previous algorithms.

4:30PM *Adaptive Fuzzy Exponent Cluster Ensemble System Based Feature Selection and Spectral Clustering* [#531]

Abdelkarim Ben Ayed, Mohamed Ben Halima and
Adel M. Alimi, REGIM-Lab.: REsearch Groups in
Intelligent Machines, University of Sfax, Tunisia

Data clustering is an important step which evolves in many pattern recognition problems and decision making applications. This step had gained great interest and several approaches were proposed to improve the clustering quality. In this context, we proposed a new ensemble clustering system based on the use of a dynamic fuzzy exponent within fuzzy C-Means clustering, an unsupervised feature selection based on the building of a strong feature vector and the use of a modified version of normalized cuts spectral image clustering algorithm applied to general data clustering. The proposed clustering algorithm was validated on eight benchmarks from UC Irvine Machine Learning Repository. Our findings are very promising and prove the effectiveness of our algorithm.

4:45PM *Fuzzy Co-clustering Induced by q-Multinomial Mixture Models* [#41]

Yuchi Kanzawa, Shibaura Institute of Technology,
Japan

In this study, a new fuzzy co-clustering algorithm based on a q-multinomial mixture model is proposed. A conventional fuzzy co-clustering model was constructed by fuzzifying a multinomial mixture model (MMM) via regularizing Kullback-Leibler divergence appearing in a pseudo likelihood of an MMM. Furthermore, a q-multinomial distribution was formulated, which acts as the Tsallis statistical counter for multinomial distributions in standard statistics. The proposed algorithm is constructed by fuzzifying a q-multinomial mixture model, by means of regularizing q-divergence appearing in a pseudo likelihood of the model. The proposed algorithm not only reduces into the q-multinomial mixture model, but also reduces into conventional fuzzy co-clustering models with specified sets of parameter values. In numerical experiments, the properties of the membership of the proposed method are observed.

5:00PM *Fuzzy clustering Algorithm with Automatic Variable Selection and Entropy Regularization* [#62]

Sara Rodriguez and Francisco de Carvalho,
Universidade Federal de Pernambuco - UFPE, Brazil

This paper proposes a partitioning fuzzy clustering algorithm with automatic variable selection and entropy regularization. The proposed method is an iterative three steps algorithm which provides a fuzzy partition, a

representative for each fuzzy cluster, and learns a relevance weight for each variable in each cluster by minimizing a suitable objective function that includes a multi-dimensional distance function as the dissimilarity measure and entropy as the regularization term. Experiments on real-world datasets corroborate the usefulness of the proposed algorithm.

5:15PM *PCM Clustering based on Noise Level* [#11]

Peixin Hou, Jiguang Yue, Hao Deng and Shuguang Liu, Department of Control Science and Engineering, Tongji University, China; School of Physics and Electronics, Henan University, China; Department of Hydraulic Engineering, Tongji University, China

Possibilistic c-means (PCM) based clustering algorithms are widely used in the literature. In this paper, we develop a noise level based PCM (NPCM)

clustering algorithm. The advantage of NPCM is that strong prior information of the dataset is not required, and NPCM needs two kinds of information that is intuitive to specify for the clustering task, i.e., information of the cluster number and information of the property of clusters. More specifically, there are two parameters in NPCM: one specifies the possibly over-specified cluster number, and the other characterizes the closeness of clusters in the clustering result. Both parameters are not required to be exactly specified. Furthermore, we find that the update of bandwidth in adaptive PCM (APCM) is a positive feedback process and the adaptive bandwidth-uncertainty mechanism adopted in NPCM makes this positive feedback process more stronger, which leads to a faster convergence rate. Experiments show that the clustering process can be effectively controlled by the parameters.

Engineering Applications of Fuzzy Sets-III

Tuesday, July 11, 4:00PM-6:00PM, Room: Aragonese, Chair: George Panoutsos and Luka Eciolaza

4:00PM *Image Detection by Possibility Distribution Dissemblance* [#415]

Charles Lesniewska-Choquet, Abdourrahmane Atto, Gilles Mauris and Gregoire Mercier, University Savoie Mont Blanc, LISTIC, France; IMT Atlantique, Telecom Bretagne, Lab-STICC, France

In this paper we present a new similarity measure between possibility distributions based on the Kullback-Leibler (KL) divergence in the domain of real numbers. The possibility distributions are obtained thanks to the DFMP probability possibility transformation [1] lying on the principle that a possibility measure can encode a family of probability measures. We consider here two particular possibility distributions built from parameter estimation of the Weibull and Rayleigh probability laws. The analytical expression of the KL divergence for the two considered possibility distributions are given, allowing a simple computation which depends on the parameters of the possibility distribution obtained. This new similarity measure is compared to the existing KL divergence for probability distributions in a context of change detection over simulated images as they provide a ground-truth of the changes required to evaluate the rate of true detection against false alarm.

4:15PM *Interval-valued Sensory Evaluation for Customized Beverage Product Formulation and Continuous Manufacturing* [#494]

Svetlin Isaev, Mohannad Jreissat, Khaled Bachour, Josie McCulloch, Christian Wagner and Charalampos Makatsoris, Cranfield University, United Kingdom; University of Nottingham, United Kingdom

Understanding of consumer preferences and perceptions is a vital challenge for the food and beverage industry. Food and beverage product development is a very complex process that deals with highly uncertain factors, including consumer perceptions and manufacturing complexity. Sensory evaluation is widely used in the food industry for product design and defining market segments. Here, we develop a two-step approach to minimize uncertainty in the food and beverage product development, including consumers as co-creators. First, we develop interval-valued questionnaires to capture sensory perceptions of consumers for the corresponding sensory attributes. The data captured is modeled with fuzzy sets in order to then facilitate the design of new consumer-tailored products. Then, we demonstrate the real-world manufacture of a personalized beverage product with a continuous food formulation system. Finally, we highlight consumers' perceptions for the corresponding sensory attributes and their fuzzy set generated agreement models to capture product acceptance for the formulated and commercial orange juice drinks, and consequently to establish that continuous beverage formulator is capable of making similar commercial products for individuals.

4:30PM *Spot Welding Monitoring System based on Fuzzy Classification and Deep Learning* [#365]

Ander Muniategui, Borja Heriz and Luka Eciolaza, IK4-LORTEK, Spain; Universtiy of Mondragon, Spain

This work is a continuation of our previous work on the development of a monitoring system of a Spot Welding production line. Here we use the process information and photographs of more than 150,000 parts to improve the predictions of the previously developed fuzzy algorithm to predict the degradation state of the electrode. And, we present an alternative method based on deep-learning that aims at substituting the image analysis software developed by us to extract values associated with the quality level of the welded parts from photographs. The deep-learning algorithm learned here is applied to compress original photographs to a 15x15 pixels size image using an encoding / decoding model. Obtained compressed images are then used to predict quality parameters from a fuzzy rule-based classification algorithm. The results are promising and show that compressed images keep the relevant information from the original image that serve to directly determine the degree of the degradation of the electrode without requiring the use of previously developed image analysis software.

4:45PM *Cognitive Load Classification in Learning Tasks from Hemodynamic Responses Using Type-2 Fuzzy Sets* [#442]

Amiyangshu De, Amit Konar, Amallesh Samanta, Souvik Biswas, Anca L Ralescu and Atulya K Nagar, Department of Electronics and Telecommunication Engineering; Jadavpur University, India; Department of Pharmaceutical Technology; Jadavpur University, India; School of Bio-Science and Engineering; Jadavpur University, India; EECS Department; University of Cincinnati, United States; Mathematics and Computer Science Department; Liverpool Hope University, United Kingdom

Although there exist recent works on fMRI based cognitive learning, there is a dearth of literature on fNIRs based studies on learning and memory. This paper provides a novel study on the cognitive load detection of subjects engaged in symbol-meaning associative learning tasks from the direct measurement of the hemodynamic response of the brain. The hemodynamic response collected during symbol-meaning associative learning tasks by subjects are pre-processed (filtered from artifacts) for extraction of 112-dimensional features, which are reduced to 20 dimensions by a meta-heuristic optimization algorithm for subsequent transfer to an interval type-2 fuzzy classifier to classify three levels of cognitive loads (High, Low and Moderate) borne by the subjects at different time slots of the learning task. Analysis undertaken reveals that the type-2 fuzzy classifier with the

proposed feature selection mechanism has a high performance in classification of the cognitive loads over 89%. Experimental analysis further reveals that the transfer of brain activation from orbitofrontal to ventrolateral prefrontal cortex takes place during transition of cognitive load from high to low. In addition, the activation of dorsolateral prefrontal cortex is also reduced during low cognitive load of subjects. These findings would offer justification of inability to handle high cognitive loads by people with under-developed/damaged orbitofrontal and dorsolateral prefrontal cortex.

5:00PM *Decentralized Piecewise PI Control for DC Microgrids* [#397]

Zhixiong Zhong and Yanzheng Zhu, Xiamen University of Technology, China; Shandong University of Science and Technology, China

This paper addresses the decentralized piecewise proportional-integral (PI) fuzzy control for direct current (DC) microgrids. The considered DC microgrid is composed of several solar photovoltaic (PV) power systems with DC/DC converters. Each PV power nonlinear system is represented by a T-S model. We propose a decentralized piecewise PI control scheme, where each PV system implements its feedback control only using its own information. Based on a piecewise Lyapunov function (PLF) combined with some matrix inequality convexification techniques, sufficient conditions for solving the design problem of the decentralized piecewise PI controller of the DC microgrid will be derived in the form of LMIs. Finally, a numerical simulation is provided to validate the advantage of the proposed method.

Generalizations of the notion of aggregation function

Tuesday, July 11, 4:00PM-6:00PM, Room: Catalana, Chair: Radko Mesiar, Javier Montero Humberto Bustince

4:00PM *About Directionally Monotone and Pre-aggregation Functions* [#297]

Laura De Miguel, Humberto Bustince, Javier Fernandez, Maria Jose Asiain, Anna Kolesarova and Radko Mesiar, Universidad Publica de Navarra, Spain; Slovak University of Technology, Slovakia

In this contribution, we discuss the role and potential of pre-aggregation functions. This class of functions has the same boundary conditions as aggregation functions, but differs in the constraints related to function increase. Specifically, monotonicity is replaced by the so-called directional monotonicity. With this work, we attempt to shed light on the relationship between aggregation and pre-aggregation functions, as well as to discuss some construction methods of pre-aggregation functions.

4:15PM *Some Properties and Construction Methods for Ordered Directionally Monotone Functions* [#295]

Mikel Sesma-Sara, Cedric Marco-Detchart, Humberto Bustince, Eurne Barrenechea, Julio Lafuente, Anna Kolesarova and Radko Mesiar, Universidad Publica de Navarra, Spain; Slovak University of Technology, Slovakia

In this work we propose a new generalization of the notion of monotonicity, the so-called ordered directionally monotonicity. With this new notion, the direction of increasingness or decreasingness at a given point depends on that specific point, so that it is not the same for every value on the domain of the considered function.

4:30PM *On the Definition of the Concept of Pre-t-conorms* [#224]

Gracaliz Dimuro, Humberto Bustince, Javier Fernandez, Jose A. Sanz, Giancarlo Lucca and Benjamin Bedregal, Universidad Publica de Navarra, Universidade Federal do Rio Grande, Spain; Universidad Publica de Navarra, Spain; Universidade Federal do Rio Grande do Norte, Brazil

The aim of this paper is to introduce the concept of pre-t-conorms, based on the notion of pre-aggregation function, which was introduced by Lucca et al. as an "aggregation" concept that it is not monotonic in all its domain. We also study the concept of light pre-t-conorms, which are non necessarily associative commutative functions with neutral element $e = 0$. We present

some properties of (light) pre-t-conorms and the classes of (light) pre-t-conorms, showing interesting examples. Finally, we present an application of pre-conorms and negations for defining directional fuzzy implication functions. We notice that the introduction of pre-t-conorms allows applications where the full monotonicity is not required (as in classification problems) and the light pre-t-conorms can be used in applications that do not require the associativity property (as in image processing and decision making).

4:45PM *A Construction Method of Internal Functions* [#412]

Daniel Paternain, Aranzazu Jurio, Humberto Bustince, Maria Jesus Campion, Irina Perfilieva and Radko Mesiar, Universidad Publica de Navarra, Spain; University of Ostrava, Czech Republic; Slovak University of Technology, Slovakia

In this work we investigate a new family of fusion functions called 'internal' fusion functions. The main characteristic of these functions is the fact that the output always corresponds to some of the given inputs. We propose a construction method and we study whether internal functions constructed in this way also satisfy properties of aggregation functions. Finally, we apply internal functions in an example of a multi-class problem, where a set of matrices must be combine into a single representative collective matrix in order to obtain better classification rates.

5:00PM *A Class of Fuzzy Implications Obtained from Triples of Fuzzy Implications* [#480]

Renata Reiser, Rosana Zanotelli, Lidiane Costa, Monica Matzenauer, Benjamin Bedregal and Ivan Mezzomo, Federal University of Pelotas, Brazil; Federal University of Rio Grande do Norte, Brazil; Rural Federal University of SemiArido, Brazil

The aim of this work is to study the class of fuzzy implication obtained by a triple (I, I_1, I_2) of fuzzy implications. Thus, this paper discusses under which conditions such functions preserve the main properties of fuzzy implications. In addition, by conjugate fuzzy implications it is shown that a fuzzy implication can be preserved by action of an order automorphism. Finally, we introduce the family of fuzzy implications obtained by taking the extended classes of triple (I, I_1, I_2) -implications verifying both generalized properties, exchange principle and distributivity in addition to, their dual construction is also considered.

5:15PM *Use of OWA Operators for Feature Aggregation in Image Classification* [#344]

Miguel Pagola, Juan I. Forcen, Edurne Barrenechea, Carlos Lopez-Molina and Humberto Bustince, Universidad Publica de Navarra, Spain

Feature aggregation is a crucial step in many methods of image classification, like the Bag-of-Words (BoW) model or the Convolutional Neural Networks (CNN). In this aggregation step, usually known as spatial

pooling, the descriptors of neighbouring elements within a region of the image are combined into a local or a global feature vector. The combined vector must contain relevant information, while removing irrelevant and confusing details. Maximum and average are the most common aggregation functions used in the pooling step. To improve the aggregation of relevant information without degrading their discriminative power for classification in this work we propose the use of Ordered Weighted operators. We provide an extensive evaluation that shows that the final result of the classification using OWA aggregation is always better than average pooling and better than maximum pooling when dealing with small dictionary sizes.

Innovations in Fuzzy Inference

Tuesday, July 11, 4:00PM-6:00PM, Room: Giardino, Chair: Christian Wagner, Derek T. Anderson
Timothy C. Havens

4:00PM *Similarity-based Non-Singleton Fuzzy Logic Control for Improved Performance in UAVs* [#94]

Changhong Fu, Andriy Sarabakha, Erdal Kayacan, Christian Wagner, Robert John and Jonathan Garibaldi, Nanyang Technological University, Singapore; University of Nottingham, United Kingdom

As non-singleton fuzzy logic controllers (NSFLCs) are capable of capturing input uncertainties, they have been effectively used to control and navigate unmanned aerial vehicles (UAVs) recently. To further enhance the capability to handle the input uncertainty for the UAV applications, a novel NSFLC with the recently introduced similarity-based inference engine, i.e., Sim-NSFLC, is developed. In this paper, a comparative study in a 3D trajectory tracking application has been carried out using the aforementioned Sim-NSFLC and the NSFLCs with the standard as well as centroid composition-based inference engines, i.e., Sta-NSFLC and Cen-NSFLC. All the NSFLCs are developed within the robot operating system (ROS) using the C++ programming language. Extensive ROS Gazebo simulation-based experiments show that the Sim-NSFLCs can achieve better control performance for the UAVs in comparison with the Sta-NSFLCs and Cen-NSFLCs under different input noise levels.

4:15PM *Developing Deep Fuzzy Network with Takagi Sugeno Fuzzy Inference System* [#527]

Shreedharkumar Rajurkar and Nishchal Kumar Verma, Indian Institute of Technology Kanpur, India

The state-of-art algorithms in computational intelligence have become better than human intelligence in some of pattern recognition areas. Most of these state-of-art algorithms have been developed from the concept of multi-layered artificial neural networks. Large amount of numerical and linguistic rule data has been created in recent years. Fuzzy sets are useful in modeling uncertainty due to vagueness, ambiguity and imprecision. Fuzzy inference systems incorporate linguistic rules intelligible to human beings. Many attempts have been made to combine assets of fuzzy sets, fuzzy inference systems and artificial neural networks. Use of a single fuzzy inference system limits the performance. In this paper, we propose a generic architecture of multi-layered network developed from Takagi Sugeno fuzzy inference systems as basic units. This generic architecture is called "Takagi Sugeno Deep Fuzzy Network". Multiple distinct fuzzy inference structures can be identified using proposed architecture. A general three layered TS deep fuzzy network is explained in detail in this paper. The generic algorithm for identification of all network parameters of three layered deep fuzzy network using error backpropagation is presented in the paper. The proposed architecture as well as its identification procedure are validated using two experimental case studies. The performance of proposed architecture is evaluated in normal, imprecise and vague situations and it is compared with performance of artificial neural network with same architecture. The results illustrate that the proposed architecture eclipses over three layered feedforward artificial neural network in all situations.

4:30PM *A new way to use Fuzzy Inference Systems in Activity-Based Cellular Modeling Simulations* [#185]

Paul-Antoine Bisgambiglia, Eric Innocenti and Pierre-Regis Gonsolin, CNRS, University of Corsica, France; Corsica Institute of Technology, France

Over the last few years, both the study and the design of IT implementations of CAM have gained a renewed interest. The success of these models in the Theory of Modelling and Simulation (TMS) relies on the structural phenomenon of emergence which makes it possible to run realistic simulations, despite lacking a modeling process for real systems. CAMs do not describe real systems with complex equations, they allow the complexity of real systems to emerge from simple interactions described locally from their cellular elements. In order to optimize simulations whatever the spatial dimension considered, the concept of activity is used. In this work, we introduce disturbances in propagation rules and we improve simulation rendering. We express a doubt in the expression of the cell's activity, i.e. we express the activity rule by means of an Fuzzy Inference System (FIS). We present a new way to use FIS, in an activity-based cellular modeling approach for fire spreading simulations.

4:45PM *Visualization and Learning of the Choquet Integral With Limited Training Data* [#230]

Anthony Pinar, Timothy Havens, Muhammad Aminul Islam and Derek Anderson, Michigan Technological University, United States; Mississippi State University, United States

The fuzzy integral (FI) is a nonlinear aggregation operator whose behavior is defined by the fuzzy measure (FM). As an aggregation operator, the FI is commonly used for evidence fusion where it combines sources of information based on the worth of each subset of sources. One drawback to FI-based methods, however, is the specification of the FM. Defining the FM manually quickly becomes too tedious since the number of FM terms scales as 2^n , where n is the number of sources; thus, an automatic method of defining the FM is necessary. In this paper, we review a data-driven method of learning the FM via minimizing the sum-of-squared error (SSE) in the context of decision-level fusion and propose an extension allowing knowledge of the underlying FM to be encoded in the algorithm. The algorithm is applied to real-world and toy datasets and results show that the extension can improve classification accuracy. Furthermore, we introduce a visualization strategy to simultaneously show the quantitative information in the FM as well as the FI.

5:00PM *Fuzzy Inferences Using Geometric Compatibility or Using Graduality and Ambiguity Constraints* [#514]

Valerie Cross and Marie-Jeanne Lesot, Miami University, United States; LIP6 - Sorbonne Universites, France

In classical logic, Modus Ponens allows to infer new knowledge in the case where the antecedent of a given rule is observed, establishing that the rule conclusion then holds. Approximate reasoning extends the principle to the

case where the observation does not totally match the rule antecedent. Several approaches have been proposed to deal with the extreme case where the observation is actually disjoint from the rule antecedent, using different principles to guide inference and avoid producing total uncertainty. This paper studies two of them, namely Geometric Compatibility Modification (GCM) and the Transformation-based Constraint-Guided Generalised Modus Ponens (T-CGMP), that respectively perform a type of approximate analogical reasoning and extend the GMP: it provides an in-depth comparison, to determine their relationships, common points and distinct features. It thus provides guidelines for the definition of fuzzy inference schemes.

5:15PM *The Fuzzy Integral for Missing Data* [#144]

Muhammad Aminul Islam, Derek Anderson, Fred Petry, Denson Smith and Paul Elmore, Mississippi State University, United States; Naval Research Laboratory, Stennis Space Center, MS, USA, United States

Numerous applications in engineering are plagued by incomplete data. The subject explored in this article is how to extend the fuzzy integral (FI), a parametric nonlinear aggregation function, to missing data. We show there is

no universally correct solution. Depending on context, different types of uncertainty are present and assumptions are applicable. Two major approaches exist, use just observed data or model/impute missing data. Three extensions are put forth with respect to just use observed data and a two step process, modeling/imputation and FI extension, is proposed for using missing data. In addition, an algorithm is proposed for learning the FI relative to missing data. The impact of using and not using modeled/imputed data relative to different aggregation operators-selections of underlying fuzzy measure (capacity)-are also discussed. Last, a case study and data-driven learning experiment are provided to demonstrate the behavior and range of the proposed concepts.

Evolutionary Fuzzy System

Tuesday, July 11, 4:00PM-6:00PM, Room: Borbonica, Chair: Hisao Ishibuchi Yusuke Nojima

4:00PM *Multi-Objective Evolutionary Granular Rule-based Classifiers: An Experimental Comparison* [#209]

Pietro Ducange, Giuseppe Mannara' and Francesco Marcelloni, SMARTEST Research Centre, eCampus University, Italy; Department of Information Engineering, University of Pisa, Italy

In this paper, we analyze and compare four multi-objective evolutionary granular rule-based classifiers. We learn concurrently the rule base, the most suitable number of granules and their parameters during the evolutionary process. Rule learning is performed by a method, which selects rules and conditions from an initial heuristically-generated rule base. The four classifiers differ for the type of granule, namely Type-1 and Type-2 fuzzy sets, and for the method used for generating the initial rule base, namely crisp and fuzzy decision tree learning algorithms. Results show that generating the initial rule base by using a fuzzy decision tree outperforms the use of the crisp decision tree. On the other hand, no statistical difference exists between the use of Type-1 and Type-2 fuzzy sets as granules.

4:15PM *A Fuzzy Rule-based System utilizing Differential Evolution with an application in vis-NIR soil spectroscopy* [#270]

Nikolaos Tsakiridis, John Theocharis and George Zalidis, Aristotle University of Thessaloniki, Greece

In this paper, we present DECO3RUM (Differential Evolution based Cooperative and Competing learning of Compact Rule-based Models), an evolutionary Mamdani Fuzzy Rule-based System for modeling problems. DECO3RUM follows the Genetic Cooperative Competitive Learning approach, and utilizes the Differential Evolution algorithm as its learning algorithm. A real world high dimensional dataset from the domain of soil science was considered to evaluate the ability of DECO3RUM to handle Big Data problems, where the number of features is significant. DECO3RUM was shown to statistically out-perform the most prevailing methodology used in soil spectroscopy, namely the Partial Least Squares Regression algorithm.

4:30PM *A Novel Approach for Internet Traffic Classification based on Multi-Objective Evolutionary Fuzzy Classifiers* [#448]

Pietro Ducange, Giuseppe Mannara', Francesco Marcelloni, Riccardo Pecori and Massimo Vecchio, SMARTEST Research Centre, eCampus University, Italy; Department of Information Engineering, University of Pisa, Italy

Internet traffic classification has moved in the last years from traditional port and payload-based approaches towards methods employing statistical measurements and machine learning techniques. Despite the success achieved by these techniques, they are not able to explain the relation between the features, which describe the traffic flow, and the corresponding traffic classes. This relation can be extremely useful to network managers for quickly handling possible network drawback. In this paper, we propose to tackle the traffic classification problem by using multi-objective evolutionary fuzzy classifiers (MOEFCs). MOEFCs are characterised by good trade-offs between accuracy and interpretability. We adopt two Internet traffic datasets extracted from two real-world networks. We discuss the results obtained both by applying a cross validation on each single dataset, and by using a dataset as training set and the other as test set. We show that, in both cases, MOEFCs can achieve satisfactory accuracy in the face of low complexity and, therefore, high interpretability.

4:45PM *Multiobjective Fuzzy Genetics-Based Machine Learning based on MOEA/D with its Modifications* [#584]

Yusuke Nojima, Koki Arahari, Shuji Takemura and Hisao Ishibuchi, Osaka Prefecture University, Japan; Southern University of Science and Technology, China

Various evolutionary multiobjective optimization (EMO) algorithms have been used in the field of evolutionary fuzzy systems (EFS), because EMO algorithms can easily handle multiple objective functions such as the accuracy maximization and complexity minimization for fuzzy system design. Most EMO algorithms used in EFS are Pareto dominance-based algorithms such as NSGA-II, SPEA2, and PAES. There are a few studies where other types of EMO algorithms are used in EFS. In this paper, we apply a multiobjective evolutionary algorithm based on decomposition called MOEA/D to EFS for fuzzy classifier design. MOEA/D is one of the most

well-known decomposition-based EMO algorithms. The key idea is to divide a multiobjective optimization problem into a number of single-objective problems using a set of uniformly distributed weight vectors in a scalarizing function. We propose a new scalarizing function called an accuracy-oriented function (AOF) which is specialized for classifier design. We examine the

effects of using AOF in MOEA/D on the search ability of our multiobjective fuzzy genetics-based machine learning (GBML). We also examine the synergy effect of MOEA/D with AOF and parallel distributed implementation of fuzzy GBML on the generalization ability.

Fuzzy Methods and Data Mining III: Clustering

Tuesday, July 11, 4:00PM-6:00PM, Room: Auditorium, Chair: José Antonio Sanz Mikel Galar

4:00PM *Fuzzy c-Shape: A new algorithm for clustering finite time series waveforms* [#218]

Fateme Fahiman, James C. Bezdek, Sarah M. Erfani, Marimuthu Palaniswami and Christopher Leckie, PhD student, Australia; Professor, United States; Lecturer, Australia; Professor, Australia

The existence of large volumes of time series data in many applications has motivated data miners to investigate specialized methods for mining time series data. Clustering is a popular data mining method due to its powerful exploratory nature and its usefulness as a preprocessing step for other data mining techniques. This article develops two novel clustering algorithms for time series data that are extensions of a crisp c-shapes algorithm. The two new algorithms are heuristic derivatives of fuzzy c-means (FCM). Fuzzy c-Shapes plus (FCS+) replaces the inner product norm in the FCM model with a shape-based distance function. Fuzzy c-Shapes double plus (FCS++) uses the shape-based distance, and also replaces the FCM cluster centers with shape-extracted prototypes. Numerical experiments on 48 real time series data sets show that the two new algorithms outperform state-of-the-art shape-based clustering algorithms in terms of accuracy and efficiency. Four external cluster validity indices (the Rand index, Adjusted Rand Index, Variation of Information, and Normalized Mutual Information) are used to match candidate partitions generated by each of the studied algorithms. All four indices agree that for these finite waveform data sets, FCS++ gives a small improvement over FCS+, and in turn, FCS+ is better than the original crisp c-shapes method. Finally, we apply two tests of statistical significance to the three algorithms. The Wilcoxon and Friedman statistics both rank the three algorithms in exactly the same way as the four cluster validity indices.

4:15PM *A New Iterative Fuzzy Clustering Algorithm for Multiple Imputation of Missing Data* [#265]

Sanaz Nikfalazar, Chung-Hsing Yeh, Susan Bedingfield and Hadi Akbarzade Khorshidi, Faculty of Information Technology, Monash University, Australia

This paper proposes a new iterative fuzzy clustering (IFC) algorithm to impute missing values of datasets. The information provided by fuzzy clustering is used to update the imputed values through iterations. The performance of the IFC algorithm is examined by conducting experiments on three commonly used datasets and a case study on a city mobility database. Experimental results show that the IFC algorithm not only works well for datasets with a small number of missing values but also provides an effective imputation result for datasets where the proportion of missing data is high.

4:30PM *Identifying Overlapping Protein Complexes in Yeast Protein Interaction Network via Fuzzy Clustering* [#372]

Lun Hu, Xiaohui Yuan and Shengwu Xiong, Wuhan University of Technology, China

The problem of identifying protein complexes is of great significance for studying the protein mechanisms in different cellular systems. It is for this reason that many computational approaches have been proposed to solve the problem. Yet few of them have endeavored to discover overlapping protein complexes, which are crucial to improve the accuracy performance. Hence, in this paper, we explore the feasibility of making use of a fuzzy clustering approach to identify overlapping protein complexes in a natural

manner. To do so, we first formulate the identification problem as an optimization problem by following certain intuitions and then develop an algorithm to solve it so that the memberships of each protein to different protein complexes can be optimized to eventually infer the protein complexes of interest. The experimental results on several yeast protein interaction networks show that our algorithm is promising in terms of accuracy.

4:45PM *Fuzzy Clustering of Structured Data: some preliminary results* [#427]

Giuseppe Vettigli and Angelo Ciaramella, University of Naples "Parthenope", Italy

In these last years, in the field of Machine Learning, there is a great interest in data structures, such as sequences, trees and graphs. In this work an unsupervised recursive learning schema for structured data clustering is introduced. The schema allows to process data organized in trees for both tree-focused and node-focused applications. The clustering approach is derived from the schema by using a Fuzzy C-Means algorithm. Some experiments are proposed to show its performances and to compare it with other known in literature for node-focused clustering.

5:00PM *Multimedia Information Retrieval Using Fuzzy Cluster-Based Model Learning* [#524]

Saeid Sattari and Adnan Yazici, Middle East Technical University, Turkey

Multimedia data, particularly digital videos, which contain various modalities (visual, audio, and text) are complex and time consuming to model, process, and retrieve. Therefore, efficient methods are required for retrieval of such complex data. In this paper, we propose a multimodal query level fusion approach using a fuzzy cluster-based learning method to improve the retrieval performance of multimedia data. Experimental results on a real dataset demonstrate that employing fuzzy clustering achieves notable improvement in the concept-based query retrieval performance.

5:15PM *An Efficient Visual Assessment of Cluster Tendency Tool for Large-scale Time Series Data Sets* [#304]

Timothy B. Iredale, Sarah M. Erfani and Christopher Leckie, Department of Computing and Information Systems, The University of Melbourne, Australia

Data visualization has always been a vital tool to explore and understand underlying data structures and patterns. However, emerging technologies such as the Internet of Things (IoT) have enabled the collection of very large amounts of data over time. The sheer quantity of data available challenges existing time series visualisation methods. In this paper we present an introductory analysis of time series clustering with a focus on a novel shape-based measure of similarity, which is invariant under uniform time shift and uniform amplitude scaling. Based on this measure we develop a Visual Assessment of cluster Tendency (VAT) algorithm to assess large time series data sets and demonstrate its advantages in terms of complexity and propensity for implementation in a distributed computing environment. This algorithm is implemented as a cloud application using Spark where the run-time of the high complexity dissimilarity matrix calculations are reduced by up to 7.0 times in a 16 core computing cluster with even higher speed-up factors expected for larger computing clusters.

Wednesday, July 12, 8:00AM-10:00AM**Software for Soft Computing-I**

Wednesday, July 12, 8:00AM-10:00AM, Room: Normanna, Chair: Jesús Alcalá-Fdez and José M.

Alonso

8:00AM *fuzzycreator: A Python-Based Toolkit for Automatically Generating and Analysing Data-Driven Fuzzy Sets* [#103]

Josie McCulloch, University of Nottingham, United Kingdom

This paper presents a toolkit for automatic generation and analysis of fuzzy sets (FS) from data. Toolkits are vital for the wider dissemination, accessibility and implementation of theoretic work and applications on FSs. There are currently several toolkits in the literature that focus on knowledge representation and fuzzy inference, but there are few that focus on the automatic generation and comparison of FSs. As there are several methods of constructing FSs from data, it is important to have the tools to use these methods. This paper presents an open-source, python-based toolkit, named *fuzzycreator*, that facilitates the creation of both conventional and non-conventional (non-normal and non-convex) type-1, interval type-2 and general type-2 FSs from data. These FSs may then be analysed and compared through a series of tools and measures (included in the toolkit), such as evaluating their similarity and distance. An overview of the key features of the toolkit are given and demonstrations which provide rapid access to cutting-edge methodologies in FSs to both expert and non-expert users.

8:15AM *A Fuzzy Extension of SPARQL based on Fuzzy Sets and Aggregators* [#58]

Jesus M. Almendros-Jimenez, Antonio Becerra-Teron and Gines Moreno, University of Almeria, Spain; University of Castilla-La Mancha, Spain

SPARQL has been adopted as query language for the Semantic Web. RDF and OWL have also been established as vocabularies to describe ontologies in this setting. While RDF/OWL/SPARQL have been designed for querying crisp information, some contexts require to manage uncertainty, vagueness and imprecise knowledge. In this paper a SPARQL extension, called FSA-SPARQL (Fuzzy Sets and Aggregators based SPARQL) is proposed, in which queries can involve different fuzzy connectives and (aggregation) operators. The language has been implemented as an extension of the ARQ Jena SPARQL engine and it is equipped with a Web tool from which queries can be executed on-line.

8:30AM *Scene selection for teaching basic visual concepts in the Refer4Learning app* [#457]

Nicolas Marin, Gustavo Rivas-Gervilla and Daniel Sanchez, University of Granada, Spain

Refer4Learning is an application that helps teachers in the early stages of children education to work on basic concepts such as color, size, or position of simple geometric objects. This type of concepts are imprecise by nature and, thus, establishing the correspondence between an expression of natural language that uses these concepts and the reality that is intended to be described is a matter of degree. In this work, we explain how Refer4Learning performs the selection of visual scenes to practice with these concepts through the use of referring expressions, which are noun phrases aimed at identifying a given object within a scene. As we shall see, this is done through the use of a specificity measure together with appropriate fuzzy models to deal with the mentioned basic visual concepts.

8:45AM *An Open-Source Software Package to Assess Similarity Measures that Compare Intuitionistic Fuzzy Sets* [#485]

Marcelo Loor and Guy De Tre, Ghent University, Dept. of Telecommunications and Information Processing, Belgium

Since intuitionistic fuzzy sets (IFSs) have been applied to solve problems in topics like decision-making or pattern recognition, the study of similarity measures aiming to compare this kind of fuzzy sets has become a challenging research subject. When proposed, a similarity measure is usually tested to demonstrate its properties and advantages over the others. However, those tests are occasionally performed using a small number of examples that do not allow a researcher or practitioner to detect potential drawbacks. In this paper, an open-source software package whereby a researcher can empirically assess several (configurations of) similarity measures while comparing IFSs that characterize experience-based evaluations is proposed and presented. By means of the proposed package, one can (1) build a large number of IFSs according to different learning scenarios, (2) compare those IFSs using existing or novel similarity measures, and (3) generate a comprehensive report about how each similarity measure reflects a perceived similarity. Reports generated by the package show that only a few of the existing similarity measures reflect properly a perceived similarity when IFSs resulting from opposite learning scenarios are compared to each other.

9:00AM *An Open Source Implementation of an Intuitionistic Fuzzy Inference System in Clojure* [#496]

Amaury Hernandez-Aguila, Mario Garcia-Valdez, Oscar Castillo and Juan-Julian Merelo Guervos, Tijuana Institute of Technology, Mexico; Universidad de Granada, Spain

The software presented in this paper is an implementation of an intuitionistic fuzzy inference system. Such type of fuzzy inference systems provide an extra layer of uncertainty, called indeterminacy, that the user can integrate in the antecedents and consequents of the fuzzy system. The additional calculations required to make an inference in this type of system need a negligible extra amount of computational resources, making it a low-cost alternative to type-2 fuzzy inference systems. At the current time, no other implementation of such type of systems exist that is open source and free of charge. The software is developed in Clojure in order to leverage the Java libraries, the JVM itself, and the capabilities of the programming language to implement concurrency in a convenient manner. However, the goal of this implementation is to provide a language-agnostic interface based in a REST API, which can be used by any programming language capable of handling HTTP requests. A comparison between a traditional type-1 fuzzy inference is provided, where the reader can observe how the indeterminacy affects the outputs of the system.

9:15AM *VICLEO: A Visualization Tool for Representing the Semantic Field of Statements* [#160]
 Martin Pereira-Farina, Jose Antonio Lopez-Fojo and Alberto Bugarin, Centre for Argument Technology (ARG-tech), University of Dundee, Dundee, DD1 4HN, United Kingdom; School of Engineering, Universidade de Santiago de Compostela, Santiago de Compostela,

15782, Spain; CiTIUS, Universidade de Santiago de Compostela, Santiago de Compostela, 15782, Spain

In this paper, we describe VICLEO, a visualization tool that performs a graph representation of the meaning of a statement based on the concepts of semantic field and semantic similarity measures. As the main novelty, VICLEO extends the concept of semantic field to a whole sentence and clusters it into fuzzy sets, where the degree of membership of the sentence components is obtained applying semantic similarity measures. Furthermore, VICLEO is endowed with a visual interactive interface which allows the user to navigate through the semantic field of the statement.

Fuzzy Set Theory in Computer Vision

Wednesday, July 12, 8:00AM-10:00AM, Room: Sveva, Chair: Chee Seng Chan Derek T. Anderson and James Keller

8:00AM *Adding Fuzzy Color Information for Image Classification* [#370]

Forcen Juan I., Miguel Pagola, Humberto Bustince, Jose M. Soto-Hidalgo and Jesus Chamorro-Matinez, Universidad Publica de Navarra, Spain; Universidad de Cordoba, Spain; Universidad de Granada, Spain

Color is a powerful feature for image analysis but it is usually not used in image classification schemes. We propose a method to combine fuzzy color information with the result obtained from a One-Versus-All classifier (OVA) trained with Bag-of-features. This method consists in weighting the outputs of the OVA classifier based on the distances between the new image to be classified and the classes. Experimental results show that our approach improves OVA classifier performance.

8:15AM *Genetic Programming Based Choquet Integral for Multi-Source Fusion* [#155]

Ryan Smith, Anderson Derek, John Ball, Alina Zare, Alvey Brendan, Josh Fairley and Stacy Howington, Electrical and Computer Engineering, Mississippi State University, United States; Electrical and Computer Engineering, University of Florida, United States; Electrical and Computer Engineering, University of Missouri, United States; U.S. Army Engineer Research and Development Center, Geotechnical and Structures Laboratory, Vicksburg,, United States

While the Choquet integral (ChI) is a powerful parametric nonlinear aggregation function, it has limited scope and is not a universal function generator. Herein, we focus on a class of problems that are outside the scope of a single ChI. Namely, we are interested in tasks where different subsets of inputs require different ChIs. Herein, a genetic program (GP) is used to extend the ChI, referred to as GpChI hereafter, specifically in terms of compositions of ChIs and/or arithmetic combinations of ChIs. An algorithm is put forth to learn the different GP ChIs via genetic algorithm (GA) optimization. Synthetic experiments demonstrate GpChI in a controlled fashion, i.e., we know the answer and can compare what is learned to the truth. Real-world experiments are also provided for the multi-sensor fusion of electromagnetic induction (EMI) and ground penetrating radar (GPR) for explosive hazard detection. Our multi-sensor fusion experiments show that there is utility in changing aggregation strategy per different subsets of inputs (sensors or algorithms) and fusing those results.

8:30AM *A Fuzzy Clustering with Bounded Spatial Probability for Image Segmentation* [#37]

Zexuan Ji and Quansen Sun, School of Computer Science and Engineering, Nanjing University of Science and Technology, China

Accurate image segmentation is an important issue in image processing, where unsupervised clustering models play an important part and have been proven to be effective. However, most clustering methods suffer from limited segmentation accuracy without considering spatial information or bounded support region for practical data. In this paper, a bounded spatial probability based fuzzy clustering algorithm is proposed for image segmentation. A bounded distribution to fit the bounded data is utilized and a new conditional probability is constructed based on the immediate neighboring probabilities. Then a parameter-free mean template is presented to impose the spatial information more precisely. Finally, the negative logarithmical conditional probability is utilized as the dissimilarity function to describe the observed data. We evaluated our algorithm against several state-of-the-art segmentation approaches on brain magnetic resonance images. Our results suggest that the proposed algorithm is more robust to noise and textures, and can produce more accurate segmentation results.

8:45AM *Single Frame Image Super Resolution via Learning Multiple ANFIS Mappings* [#521]

Jing Yang, Changjing Shang, Ying Li and Qiang Shen, Northwestern Polytechnical University, Aberystwyth University, China; Aberystwyth University, United Kingdom; Northwestern Polytechnical University, China

This paper proposes a new approach for single frame image super resolution using multiple ANFIS (Adaptive Network-based Fuzzy Inference System) mappings. It presents an implemented learning system that captures the relationship between a low resolution (LR) image patch space and a high resolution (HR) one given an external image database. In particular, a collected large number of LR and HR image patch pairs are divided into different groups with a clustering method. For each clustered group of the training samples, an ANFIS mapping is learned for super resolution (SR). The non-local means filter is subsequently employed to suppress the displeasing artefacts of the resulting reconstructed HR image. The proposed approach is evaluated on a range of natural images and compared with a number of existing state-of-the-art SR algorithms, demonstrating its effectiveness.

9:00AM *Multidimensional Fuzzy Sets for Texture Modelling Adapted to User Profiles* [#243]

Pedro Manuel Martinez-Jimenez, Jesus Chamorro-Martinez, Jose Manuel Soto-Hidalgo and Javier Rodriguez-Perez, University of Granada, Spain; University of Cordoba, Spain

The analysis of the perceptual properties of texture plays a fundamental role in tasks where some interaction with subjects is needed. In order to face the

imprecision related to these properties, several fuzzy approaches can be found in the literature, but they do not properly take into account the subjectivity of users. In this paper, a generic technique is proposed in order to adapt any multidimensional fuzzy set to the different perceptions of texture properties that a particular user can have. This way, we combine the improvement in the texture characterization given by the use of several computational measures as reference set with the adaptation to the subjectivity of the human perception. In the proposed adaptation method, the membership functions are automatically transformed on the basis of the information given by the user.

Business Processes and Fuzzy Logic in Monitoring, diagnosis and prognosis

Wednesday, July 12, 8:00AM-10:00AM, Room: Santa Lucia, Chair: Hamid Reza Karimi and Mario Luca Bernardi

8:00AM *Car Hacking Identification through Fuzzy Logic Algorithms* [#128]

Martinelli Fabio, Mercaldo Francesco, Nardone Vittoria and Santone Antonella, IIT-CNR, Italy; University of Sannio, Italy

Modern vehicles have lots of connectivity, this is the reason why protect in-vehicle network from cyber-attacks becomes an important issue. Controller Area Network (CAN) is a de facto standard for the in-vehicle network. However, lack of security features of CAN protocol makes vehicles vulnerable to attacks. The message injection attack is a representative attack type which injects fabricated messages to deceive original Electronic Control Units (ECUs) or to cause malfunctions. In this paper we propose a method able to detect four different type of attacks targeting the CAN protocol adopting fuzzy algorithms. We obtain encouraging result in attack identification, with a precision ranging from 0.85 to 1 using the fuzzy NN algorithm in the identification of attacks targeting CAN protocol.

8:15AM *A Fuzzy-based Process Mining Approach for Dynamic Malware Detection* [#167]

Mario Luca Bernardi, Marta Cimitile, Fabio Martinelli and Francesco Mercaldo, Giustino Fortunato University, Benevento, Italy; Unitelma Sapienza, Roma, Italy; Institute for Informatics and Telematics, National Research Council of Italy (CNR), Pisa, Italy

Mobile systems have become essential for communication and productivity but are also become target of continuous malware attacks. New malware are often obtained as variants of existing malicious code. This work describes an approach for dynamic malware detection based on the combination of Process Mining (PM) and Fuzzy Logic (FL) techniques. The firsts are used to characterize the behavior of an application identifying some recurring execution expressed as a set of declarative constraints between the system calls. Fuzzy logic is used to classify the analyzed malware applications and verify their relations with the existing malware variants. The combination of the two techniques allows to obtain a fingerprint of an application that is used to verify its maliciousness/trustfulness, establish if it belongs from a known malware family and identify the differences between the detected malware behavior and the other variants of the some malware family. The approach is applied on a dataset of 3000 trusted and malicious applications across twelve malware families and has shown a very good discrimination ability that can be exploited for malware detection and family identification.

8:30AM *A Fuzzy-based Autoscaling Approach for Process Centered Cloud Systems* [#610]

Giovanni Acampora, Mario Luca Bernardi, Marta Cimitile, Genoveffa Tortora and Autilia Vitiello, University of Naples Federico II, Italy; University Giustino Fortunato, Italy; University Unitelma Sapienza, Italy; University of Salerno, Italy

In the last years, the growing adoption of cloud-based multi-tiers systems has strongly increased the levels of resource sharing among companies, improving the enterprise efficiency, thanks to a refined business dynamism and a rapid decrease in costs. However, in spite of their advantages, this new business model highlights the emergence of new computational approaches aimed at the distribution and the optimization of resources sharing along so-called multi-tenants system, i.e., cloud-based architecture where a single instance of software runs on a single server and serves multiple companies (tenants). This paper faces this challenging gap by proposing an auto-scaling cloud computing multi-tenancy architecture where process mining and fuzzy-based load-balancing systems synergistically interact to provide an improved and optimized resource management distribution. A case study is carried out to show the proposed architecture in operation.

8:45AM *Hybrid diagnosis of inter- turn short circuit for aircraft applications using SVM - MBF* [#305]

Romain Breuneval, Guy Clerc, Babak Nahid-Mobarakeh and Badr Mansouri, SAFRAN Electronics and Defense, Avionics Division, France; Univ Lyon, UCB Lyon 1, CNRS, AMPERE, France; GREEN, Institut National Polytechnique de Lorraine (INPL), Nancy University, France

The automatic diagnosis of systems is essential in several industries such as aeronautics. This paper introduces a method to diagnose systems with respect to the constraints of the aeronautics field: robustness and low computation costs. The proposed methodology is based on the combination of Support Vector Machine and Fuzzy Membership Functions (SVM-MBF). The distances, which are computed by the SVM, are fuzzified in order to give a degree of confidence in the classification. Besides, using SVM-MBF allows estimating the severity of a fault. The architecture of the proposed diagnosis system consists in putting in series one classifier to detect faults, with a set of classifiers, one per fault, to assess the severity. The method is applied to the diagnosis of inter- turn short-circuits of a Permanent Magnet Synchronous Machine (PMSM). The data come from measurements performed on a machine designed for aeronautics applications. The method is evaluated in terms of robustness and computation time by using cross validation. The results show the suitability of the methodology for aeronautics applications.

9:00AM *A Heterogeneous Defense Method using Fuzzy Decision Making* [#601]

A.A. Rezaei, E. Lotfi, A. Khosravi and S. Nahavandi, Payam-e Noor University, Iran; Torbat-e-Jam Branch, Azad University, Iran; Center for Intelligence Systems Research, Deakin University,, Australia; Alfred Deakin Professor, Australia

Denial of service flood attacks are among the most common and powerful attacks which abuse the computational resources and the bandwidth of a network. In this paper, a heterogeneous defense method is proposed based on a combination of the Software Defined controller and fuzzy decision making. Numerical results show that the proposed method has a lower computational load and response time compared to the traditional methods centralized in the controller.

9:15AM *A Fuzzy Multi-criteria Decision Making Model for Menu Engineering* [#357]

Mary Tom and Katerina Annaraud, Central Queensland University, Australia; University of South Florida, United States

Menu remains a key element in influencing the success of restaurants which is very dynamic and highly competitive with a high failure rate within the first three years of operation. Menu engineering refers to the specific techniques used to evaluate performance of individual menu items leading to strategic decision. Many influencing elements are consolidated to two elements of popularity index and contribution margin providing four different combinations that can be used to choose decision options. Decision makers carry out menu engineering against manually set target values which are imprecise and choice of strategic options becomes erroneous and tedious. As a step toward providing a more powerful decision making tool this study presents a fuzzy multi- criteria decision making model to choose strategy decision options that extends the set of combinations from four to nine. The model uses trapezoidal fuzzy numbers for normalization and linguistic variables for fuzzification. The applicability of the model is tested using thirty menu items in four categories.

Fuzziness and the Mathematics of Many-Valuedness

Wednesday, July 12, 8:00AM-10:00AM, Room: Catalana, Chair: Didier Dubois, Stephen E. Rodabaugh Austin Melton

8:00AM *Complete Many-Valued Lattices* [#8]

Patrik Eklund, Javier Gutierrez Garcia, Ulrich Hoehle and Jari Kortelainen, University Umea, Umea, Sweden; Universidad del Pais Vasco, UPV/EHU, Spain; Bergische Universitaet, Wuppertal, Germany; Mikkeli Univerity of Applied Sciences, Finland

Let Sup be the category of complete lattices and join preserving maps. The aim of this talk is to show that the theory of complete many-valued lattices exists. For this purpose we recall the concept of many-valued preordered sets and show that the category of many-valued join-complete lattices is isomorphic to the category of right modules in Sup --- a theorem which goes back to I. Stubbe 2006 in a more general context given by quantaloid enriched categories. Finally, the presented theory will be explained by some natural examples.

8:20AM *Non-Commutativity and Many-Valuedness: The Topological Representation of the Spectrum of C^* -Algebras* [#9]

Patrik Eklund, Javier Gutierrez Garcia, Ulrich Hoehle and Jari Kortelainen, University Umea, Umea, Sweden; Universidad del Pais Vasco, UPV/EHU, Spain; Bergische Universitaet, Wuppertal, Germany; Mikkeli Univerity of Applied Sciences, Finland

In the past there have been made various attempts to define the spectrum of a non-commutative C^* -algebra. But all these definitions have certain drawbacks --- e.g. C.J. Mulvey's definition does not coincide with the standard definition of the spectrum in the commutative case. The aim of our talk is to give an alternative definition of the spectrum which does not suffer under this deficit --- i.e. coincides with the standard situation in the commutative setting. For this purpose we recall some properties of balanced and bisymmetric quantales, introduce a definition of the spectrum of a C^* -algebra working for the general case and develop subsequently its topological representation.

8:35AM *Smarandache 2-Structures on Hoop-Algebras* [#18]

Reza Tayebi Khorami and Arsham Borumand Saeid, Department of Mathematics, Ahvaz Branch, Islamic Azad university, Ahvaz, Iran, Iran; Department of Pure Mathematics, Faculty of Mathematics and Computer, Shahid Bahonar University of Kerman, Kerman, Iran., Iran

In this paper we define the Smarandache hoopalgebras and Q-Smarandache filters, we obtain some related results. After that, by considering the notions of these filters we determine relationships between filters in hoop-algebras and Q-Smarandache filters in hoop-algebras. Finally, we introduce the concept of Smarandache 2-structure and Smarandache 2-filter on hoop-algebras.

8:50AM *Modules in Health Classifications* [#82]

Patrik Eklund, Ulrich Hoehle and Jari Kortelainen, Umea University, Sweden; Bergische Universitaet Wuppertal, Germany; Mikkeli University of Applied Sciences, Finland

In applications, for example in health care, many-valuedness modelled using quantales plays an important role. The paper presents variations of the three chain modules over unitalization of the three chain quintile (three chain is the smallest possible quantale to model many-valuedness), thus, variations of right actions are given. From application point of view, it is then possible to choose suitable modules when modelling, for example, the causalities between disease, intervention and functioning. Effects of drug interactions in presence of multiple diseases, and as affecting functioning, adds to this complexity. Health care communities and professionals comply with a range classifications and terminologies, also including scales to qualify strength or hierarchies of evidence (in the sense of evidence-based medicine) or interaction, or as related to levels of functioning. Such hierarchies adopted in health care are ad hoc as compared to the potentially algebraic and logic structures of terminology infused reasoning. In this paper we show how these hierarchies canonically derive as actions where transitions appear as levels in hierarchies of evidence. We will also see how three-valuedness related to health conditions, rather than two-valuedness, is the generator many-valuedness related to strength of evidence.

9:05AM *The Structure of Many-Valued Relations III. Tied Relational Systems* [#255]

M. Emilia Della Stella, Cosimo Guido and Laura Ruzittu, Department of Mathematics and Physics - University of Salento, Italy

In this paper fuzzy (tied) relational systems are considered which are the objects of semicategories whose morphisms constitute a general variable-basis approach to fuzzy Galois connections and conjugated pairs. Useful applications to some kinds of algebraic structures are outlined.

9:20AM *Embedding TopSys into a Topological Category* [#541]

Jeffrey Denniston, Austin Melton and Stephen Rodabaugh, Kent State University, United States; Youngstown State University, United States

The purpose of this paper is to make a case for the value of many-valued mathematics, often called fuzzy mathematics. We believe there may be a difference between many-valued mathematics and fuzziness, as used by

those who work with fuzzy logic and fuzzy set theory and applications thereof. We think that most, if not all, fuzzy mathematics is many-valued. However, for this paper, the difference between many-valued mathematics and fuzzy mathematics, if a difference exists, is not important. We are, in this paper, content to show that many-valued mathematics can contribute to mathematics. We do understand that for those mathematicians who feel that many-valued mathematics does not have a place in mathematics this paper will not cause them to embrace many-valued mathematics, but we would like for some of them to consider that many-valued mathematics might be able to contribute to mathematics. In this paper, we give an example of a mathematical construction which was created and defined in part to help computer scientists understand and be able to use topological ideas and concepts in their work as computer scientists. Thus, one would think that this construction, called topological systems, would be topological (as defined later). However, it seems that topological systems are clearly not topological. Thus, an interesting question is can topological systems be made topological, or said more mathematically, can topological systems be embedded into something which is topological.

Soft Subspace Clustering

Wednesday, July 12, 8:00AM-10:00AM, Room: Giardino, Chair: Marie-Jeanne Lesot, Christophe Marsala, Nikhil R. Pal Arthur Guillon

8:00AM *Cluster Identification and Scaling Methods based on Comparative Quantification for Dissimilarity Data* [#101]

Mika Sato-Ilic and Peter Ilic, University of Tsukuba, Japan; Tokyo University of Foreign Studies, Japan

This paper proposes two methods. One is the cluster identification method for 3-way dissimilarity data among objects over times (or subjects) and the other is the cluster scaling method for dissimilarity data among objects. Both methods are based on the comparative quantification model which can obtain the quantitative amount of relationship between a pair of clusters or relationship between a cluster and a basis which spans a subspace constructed a scale. The merits of these methods are that we can obtain "comparability" of obtained clusters over times (or subjects) and supply an "adaptable scale" for observed dissimilarity between a pair of objects, in order to reduce the number of dimensions of the observed data and explain the dissimilarity relationships among objects in the lower dimensional subspace. Numerical examples to investigate the educational effectiveness by using the cognitive 3-way dissimilarity data of students demonstrate a better performance for the proposed methods.

8:15AM *Noise Rejection Schemes for FCM-type Co-clustering Based on Uniform Noise Distribution* [#264]

Nami Yamamoto, Katsuhiko Honda, Seiki Ubukata and Akira Notsu, Osaka Prefecture University, Japan

Fuzzy co-clustering is an extension of FCM-type clustering, where the within-cluster-error measure of FCM is replaced by the aggregation degree of two types of fuzzy memberships with the goal being to estimate object-item pairwise clusters from their cooccurrence information. This paper proposes a noise rejection scheme for FCM-type co-clustering models, which is constructed based on the probabilistic co-clustering concept. Noise FCM was achieved by introducing an additional noise cluster into FCM, where the noise cluster was assumed to have a uniform prototype distribution. A similar concept was implemented for probabilistic concept-based co-clustering for robust estimation. The main contribution of this paper is to demonstrate that the uniform distribution concept can also be useful in FCMtype co-clustering models, even though their objective functions are not designed based on probabilistic concepts.

8:30AM *A Fuzzy Co-clustering Model for Three-modes Relational Cooccurrence Data* [#272]

Katsuhiko Honda, Yurina Suzuki, Mio Nishioka, Seiki Ubukata and Akira Notsu, Osaka Prefecture University, Japan

Fuzzy co-clustering is a basic technique for analyzing co-cluster structures in cooccurrence information among objects and items. When we have not only cooccurrence information among objects and items but also intrinsic relation among items and other ingredients, it is expected that we can find more useful co-cluster structures among three-modes cooccurrence relation. In this paper, the conventional fuzzy clustering for categorical multivariate data (FCCM) algorithm is extended by utilizing three-types of fuzzy memberships for objects, items and ingredients, where the aggregation degree of three elements in each co-cluster is maximized through iterative updating of memberships. The characteristic features of the proposed method is demonstrated through several numerical experiments including a school lunch calendar analysis.

8:45AM *Laplacian Regularization For Fuzzy Subspace Clustering* [#392]

Arthur Guillon, Marie-Jeanne Lesot and Christophe Marsala, UPMC - LIP6, France

This paper studies a well-established fuzzy subspace clustering paradigm and identifies a discontinuity in the produced solutions, which assigns neighbor points to different clusters and fails to identify the expected subspaces in these situations. To alleviate this drawback, a regularization term is proposed, inspired from clustering tasks for graphs such as spectral clustering. A new cost function is introduced, and a new algorithm based on an alternate optimization algorithm, called Weighted Laplacian Fuzzy Clustering, is proposed and experimentally studied.

9:00AM *A new efficient fuzzy cluster validity index: Application to images clustering* [#430]

Fatma Haouas, Zouhour Ben Dhiaf, Atef Hammouda and Basel Solaiman, Faculty of Sciences of Tunis Laboratory: LIPAH, Tunisia; IMT Atlantique Bretagne, ITI departeent, France

Finding the appropriate number of clusters in the absence of prior information is a hard and sensitive problem in clustering and data analysis. In this paper,

we present a new cluster validity index (CV I) called HF able to find the optimal number of clusters present in a given data. The HF index is based on the membership partition. It can be seen as the generalisation of the Wu-and-Li (WL) and Tang (T) indices. Its particularity is the integration of a generalised ad-hoc punishing term, on the one hand, and the involving of median between centroids multiplied by the average of data per cluster for computing the separation, on the other hand. These contributions allow avoiding the monotony from which suffer the majority of CV Is and obtaining a precise evaluation. The optimal number of clusters Cop corresponds to the minimum of the HF index. In order to ensure the effective choice of the optimal number of clusters, we propose an algorithm based on the HF and WL indices. The performance of the proposed index and algorithm are demonstrated through different experimentations on images clustering using the algorithm Fuzzy-C-Means (FCM). The HF index's ability to appropriately determine the number of clusters is compared with those of WL, T and the Xi-Beni (XB) indices with different initialisations.

9:15AM *SHCoClust, a Scalable Similarity-based Hierarchical Co-clustering Method and its Application to Textual Collections* [#529]

Xinyu Wang, Julien Ah-Pine and Jerome Darmont,
Universite de Lyon, Lyon2, ERIC, EA3083, France

In comparison with flat clustering methods, such as K-means, hierarchical clustering and co-clustering methods are more advantageous, for the reason

that hierarchical clustering is capable to reveal the internal connections of clusters, and co-clustering can yield clusters of data instances and features. Interested in organizing co-clusters in hierarchies and in discovering cluster hierarchies inside co-clusters, in this paper, we propose SHCoClust, a scalable similarity-based hierarchical co-clustering method. Except possessing the above-mentioned advantages in unison, SHCoClust is able to employ kernel functions, thanks to its utilization of inner product. Furthermore, having all similarities between 0 and 1, the input of SHCoClust can be sparsified by threshold values, so that less memory and less time are required for storage and for computation. This grants SHCoClust scalability, i.e. the ability to process relatively large datasets with reduced and limited computing resources. Our experiments demonstrate that SHCoClust significantly outperforms the conventional hierarchical clustering methods. In addition, with sparsifying the input similarity matrices obtained by linear kernel and by Gaussian kernel, SHCoClust is capable to guarantee the clustering quality, even when its input being largely sparsified. Consequence, up to 86% time gain and on average 75% memory gain are achieved.

Fuzzy Interpolation

Wednesday, July 12, 8:00AM-10:00AM, Room: Borbonica, Chair: Laszlo Koczy, Shyi-Ming Chen, Ying Li Qiang Shen

8:00AM *Interpolation in Homogenous Fuzzy Signature Rule Bases* [#35]

Laszlo T. Koczy, Budapest University of Technology and Economics, Hungary

Fuzzy signature sets (FSigSets) are extensions of the original fuzzy set concept, and also of the Vector Valued Fuzzy Set notion. In a FSigSet rule base the (input) universe of discourse X is mapped into a set of hierarchically grouped fuzzy sets, and each element of X has a "membership degree" consisting of a rooted tree with membership degrees at each leaf and aggregations at the intermediate vertices. The structure of the tree is identical for each element in the case of homogenous FSigSets, and so are the aggregations, depending only on the position of the vertex. Interpolation in fuzzy rule bases allows the calculation of a conclusion in the output universe Y belonging to an observation even if there are gaps in the rule base and the observation does not intersect with any of the antecedent sets. The key question here is how to determine the degree of similarity, or inversely, the distance, of any observation from the surrounding antecedents of the rules in the base, so that the distance incorporates the information involved with the close connection of the features in the sub-groups, and the aggregations expressing the form of this connection. A solution is proposed, and a pair of numerical examples is presented.

8:15AM *Feature Ranking-guided Fuzzy Rule Interpolation* [#59]

Fangyi Li, Changjing Shang, Ying Li and Qiang Shen,
Aberystwyth University, United Kingdom;
Northwestern Polytechnical University, China

Fuzzy rule interpolation (FRI) provides an alternative means to make inference with a sparse rule base, rather than directly resulting in failed reasoning when no rules can be fired for an input observation. However, existing approaches to FRI typically assume that rule antecedents are of equal significance in the implementation of interpolation, thereby often leading to less accurate interpolated results. Having taken notice of feature selection (FS) techniques being capable of selecting (subsets of) informative features, providing a mechanism of evaluating and ranking features, this work employs FS to score the individual rule antecedents in a given rule

base. In particular, the computation of individual scores is enabled by the introduction of an innovative reverse engineering technique that artificially creates a set of training samples from a given sparse rule base. The antecedent scores are integrated within the scale and move transformation-based FRI algorithm (though other FRI approaches may employ the same idea), forming a novel feature ranking-guided FRI method. The work is systematically examined, by utilising six different FS techniques and comparing over eight benchmark classification problems, demonstrating improved classification performance.

8:30AM *D-FRI-WinFirewall: Dynamic Fuzzy Rule Interpolation for Windows Firewall* [#124]

Nitin Naik, Ren Diao, Changjing Shang, Qiang Shen and Paul Jenkins, Ministry of Defence, United Kingdom; Wandera Ltd., United Kingdom; Aberystwyth University, United Kingdom

Dynamic fuzzy rule interpolation (D-FRI) consists of functionalities of fuzzy rule interpolation and dynamically refinement of the fuzzy rule base. It can be integrated with any fuzzy intelligent system to extend the system's capabilities in addition to its normal fuzzy reasoning. Systems security is one of the areas that require dynamic monitoring due to the nature of possible threats; static rule-based systems cannot cover all reoriented security threats accurately in the long run. D-FRI provides a possible solution to such problems, potentially making various security tools (e.g., those for firewall, intrusion detection and traffic analysis) more effective. As a particular application, this paper exploits D-FRI to dynamically support Microsoft Windows Firewall, resulting in a robust system named D-FRIWinFirewall. Given the general utility of Windows Firewall, the impact of this work is ubiquitous. The work reported here focusses on the monitoring and prevention of denial of service (DoS) attacks, which is not possible by utilising the standard Windows Firewall alone. In particular, two sub-systems are designed, implemented and tested within D-FRI-WinFirewall, with an effort to monitor and prevent the two most severe types of DoS attack: ICMP DoS and UDP DoS, leading the Windows Firewall to outperform popular and expensive firewalls, which are yet unable to handle DoS attacks.

8:45AM *Intrusion Detection System by Fuzzy Interpolation* [#517]

Longzhi Yang, Jie Li, Gerhard Fehringer, Phoebe Barraclough, Graham Sexton and Yi Cao, Northumbria University, United Kingdom; Nanjing Customs District P.R. China, China

Network intrusion detection systems identify malicious connections and thus help protect networks from attacks. Various data-driven approaches have been used in the development of network intrusion detection systems, which usually lead to either very complex systems or poor generalization ability due to the complexity of this challenge. This paper proposes a data-driven network intrusion detection system using fuzzy interpolation in an effort to address the aforementioned limitations. In particular, the developed system equipped with a sparse rule base not only guarantees the online performance of intrusion detection, but also allows the generation of security alerts from situations which are not directly covered by the existing knowledge base. The proposed system has been applied to a well-known data set for system validation and evaluation with competitive results generated.

9:00AM *Dynamic QoS Solution for Enterprise Networks Using TSK Fuzzy Interpolation* [#518]

Jie Li, Longzhi Yang, Xin Fu, Fei Chao and Yanpeng Qu, Northumbria University, United Kingdom; Xiamen University, China; Dalian Maritime University, China

The Quality of Services (QoS) is the measure of data transmission quality and service availability of a network, aiming to maintain the data, especially delay-sensitive data such as VoIP, to be transmitted over the network with the required quality. Major network device manufacturers have each developed their own smart dynamic QoS solutions, such as AutoQoS

supported by Cisco, CoS (Class of Service) by Netgear devices, and QoS Maps on SROS (Secure Router Operating System) provided by HP, to maintain the service level of network traffic. Such smart QoS solutions usually only work for manufacture qualified devices and otherwise only a pre-defined static policy mapping can be applied. This paper presents a dynamic QoS solution based on the differentiated services (DiffServ) approach for enterprise networks, which is able to modify the priority level of a packet in real time by adjusting the value of Differentiated Services Code Point (DSCP) in Internet Protocol (IP) header of network packets. This is implemented by a 0-order TSK fuzzy model with a sparse rule base which is developed by considering the current network delay, application desired priority level and user current priority group. DSCP values are dynamically generated by the TSK fuzzy model and updated in real time. The proposed system has been evaluated in a real network environment with promising results generated.

9:15AM *A Local Transformation-based Constraint-guided GMP Compatible with an Interpolation Scheme* [#573]

Marie-Jeanne Lesot and Bernadette Bouchon-Meunier, LIP6 - UPMC, France; LIP6 - CNRS, France

The T-CGMP inference scheme combines the GMP principles with additional constraints to guide inference in the case where the observation does not match the rule premise. This paper studies its exploitation in the case where several rules are available, in particular considering the case of two rules: it proposes a local variant of T-CGMP and examines its behaviour in this interpolation-like framework, highlighting its specific features, in particular the original uncertain outputs it produces to keep track of shape mismatches. The resulting inference scheme can thus be seen as an intermediary between GMP and interpolation.

Wednesday, July 12, 2:30PM-4:30PM**Software for Soft Computing-II**

Wednesday, July 12, 2:30PM-4:30PM, Room: Normanna, Chair: Jesús Alcalá-Fdez and José M. Alonso

2:30PM *A Tool to Perform Semantic and Imprecise Queries on Non-Scalar Data* [#492]

Carmen Martinez-Cruz, Jose Maria Serrano and Maria Amparo Vila, University of Jaen, Spain; University of Granada, Spain

Imprecision in queries has been managed using fuzzy logic techniques in the last few decades. Fuzzy logic techniques represent uncertainty formally and it allows to manage imprecision on scalar values in an easy and accurate way. The problem arises when users want to deal with semantics and non-scalar data at once. In this situation, fuzzy logic helps us to manage uncertainty, but it lacks of the flexibility that the semantic properties of words imply. Nowadays, ontologies have addressed this problem by the establishment of the semantic relationships among terms. Here, we present a software that allows us to combine fuzzy and semantic queries on non-scalar data. As a proof of concept, we will show some examples of queries performed on a real database about olive trees plantations.

2:45PM *Extending IEEE Std 1855 for designing ArduinoTM-based Fuzzy Systems* [#592]

Giovanni Acampora and Autilia Vitiello, University of Naples Federico II, Italy; University of Salerno, Italy

IEEE Std 1855 is the first IEEE standard technology developed in the area of fuzzy logic. Its main characteristic is the interoperability, a design feature that enables system designers to develop fuzzy inference engines without taking into account the hardware/software constraints imposed by the specific

architecture on which the system will be deployed. Thanks to this feature, a fuzzy system can be integrated into different types of architectures without any need to carry out porting strategies. This feature is particularly crucial in the area of embedded systems where, for each kind of device, a variety of applications, communication protocols, software libraries and programming tools, exists. In this context, ArduinoTM technology represents one of the most popular architectures, thanks to its ease of development and prototyping. This paper shows how the native extendability feature of IEEE Std 1855 enables the design of a rule-based fuzzy systems in fully interoperable fashion on ArduinoTM architectures and, as a consequence, allows designers to focus on fuzzy concepts, without any need to consider the hardware/software details related to the specific ArduinoTM system.

3:00PM *rLDCP: R Package for Text Generation from Data* [#161]

Patricia Conde-Clemente, Jose M. Alonso and Gracian Trivino, Universidad de Oviedo, Spain; Universidade de Santiago de Compostela, Spain; Phedes Lab, Spain

The generation of text reports from numerical and symbolic data is getting the attention of many researchers. This paper presents an R package useful to develop computational systems able to generate linguistic descriptions of complex phenomena. It generates text reports from numerical and symbolic data related to the phenomena under consideration. This is an implementation of our previous research work that is supported by the computational theory of perceptions grounded in the fuzzy sets theory. Developing open source software while we follow the key issues (novelty, usability, interoperability, and relevance) will facilitate the adoption of this

new discipline in the research community and industry. We present illustrative examples that show how to use this new R package. The examples reveal that the package is ready to become a relevant tool in the research field of text generation from data.

3:15PM *Enhancing JFCS Software with a New Mapping Module. Filling the Semantic Gap from Pixels to Meaningful Fuzzy Colors* [#249]

Jose Manuel Soto-Hidalgo, Pedro Manuel Martinez-Jimenez, Jesus Chamorro-Martinez and Daniel Sanchez, University of Cordoba, Spain; University of Granada, Spain

This paper introduces a new way of interaction in JFCS Software where users can view and navigate easily between different combinations of fuzzy colors and pixels in images. Fuzzy colors allow introducing semantics in the description of color by using linguistic labels, filling the semantic gap between the color representation in computers and the subjective human perception. JFCS (Java Fuzzy Color Space) Software, an open source (GPLv3) software with a user-friendly interface, provides an easy framework to design and automatically obtain customized fuzzy color spaces on the basis of an approach proposed by the authors in previous work. This new functionality in JFCS endows it with a very useful tool to visually analyze correspondences between pixels and fuzzy colors in images. Users can obtain combined mapped images where regions, corresponding to a combination of color concepts, are highlighted. In addition, users can describe and interact, in a simple and visual way, with colors present on a given image in terms of fuzzy colors.

Human Symbiotic Systems

Wednesday, July 12, 2:30PM-4:30PM, Room: Sveva, Chair: Tomohiro Yoshikawa and Yoichiro Maeda

2:30PM *Instruction Recognition Used Gaze and EMG Information for Omni-directional Wheelchair* [#169]

Yoichiro Maeda, Ritsumeikan University, Japan

In recent years, the development of nursing and welfare robots intended for people with disabilities and elderly has been advanced. The research of the method to transmit human intentions to the robot by using the biological information of the operator is proceeding. In this research we propose a method to perform the locomotive control of omnidirectional wheelchair by a gaze instruction system based on the human intention estimated by using fuzzy reasoning, and an instruction system using electromyogram (EMG) of operator's forearm and fuzzy reasoning. We performed the operating experiment using gaze and EMG measurement device, and we confirmed that the operator can perform the moving control of wheelchair according to his/her instructions.

2:45PM *Identification of Medial Proximal Stem Shape by Measurement of Five Ultrasound Probes Inside Stem Model* [#328]

Ayaka Gonda, Kouki Nagamune and Kiyonori Mizuno, Graduate School of Engineering University of Fukui, Japan; Anshin Hospital, Japan

Total Hip Arthroplasty (THA) recently becomes more famous in Japan. The number of operations is increasing more and more because of longevity. THA requires subjectivity judgement of surgeons due to lack of proper measurement system for surgery. Especially, inserting artificial femoral joint is important for clinical outcome (e.g., pain, and loosening.). In addition, femoral stem which is one of the artificial joints, has a shape fitting to femur bone. Therefore, the insertion angle strongly relates the fixation degree of artificial joint. This study aims to specify the curve shape of medial proximal

3:30PM *KEEL meets KNIME* [#193]

Corrado Mencar, Anna Maria Fanelli and Mirko Russo, University of Bari "A. Moro", Italy

We propose an approach to integrate the KEEL software tool for knowledge discovery within the KNIME Analytics platform. The integration approach is non-invasive as it does not require the modification of source code in neither of the tools. As a result of the integration, it is possible to use the algorithms provided with KEEL --- including many fuzzy methods --- directly in KNIME workflows, thus taking the advantages of both tools. We report two simple integration examples, which show the effectiveness of the proposed approach in building data analysis workflows involving KEEL methods, possibly along with methods provided by other knowledge discovery tools like WEKA.

3:45PM *Mining Association Rules in R Using the Package RKEEL* [#284]

Oliver Sanchez, Jose M. Moyano, Sanchez Luciano and Alcala-Fdez Jesus, University of Granada, Spain; University of Cordoba, Spain; University of Oviedo, Spain

The discovery of fuzzy associations comprises a collection of data mining methods used to extract knowledge from large data sets. Although there is an extensive catalog of specialized algorithms that cover different aspects of the problem, the most recent approaches are not yet packaged in mainstream software environments. This makes it difficult to incorporate novel association rules methods to the data mining workflow. In this paper an extension of the RKEEL package is described that allows calling from the programming language R to those association rules methods contained in KEEL, which is one of the most comprehensive open source software suites. The potential of the proposed tool is illustrated through a case study comprising seven real-world datasets.

part of stem by measuring the curve with ultrasound device. This study develops five probes with small size which enables us to embed the probes into inside stem. The probes measure reflected echoes from boundary of the femur contour, then the propagated time of the echo was converted into the distance from the surface of the probes and the femur contour by using ultrasound velocity. The experiments were performed with two femur models. As a result, the proposed system could show the contour which is corresponding with real shape. We indicated usefulness of the method using ultrasound proves for measuring a curve stem inside.

3:00PM *Influence of Emotional Expression of Real Humanoid Robot to Human Decision-Making* [#327]

Kayukawa Yuki, Takahashi Yasutake, Tsujimoto Takuya, Terada Kazunori and Inoue Hiroyuki, University of Fukui, Japan; Gifu University, Japan

Conventional studies have suggested that emotion representation of a robot affects human action decision in human-robot communication. The influence of emotional expression of the robot to the human decision-making can be represented by a simple fuzzy inference model. However, they often use emotion expression by mimicking human facial expression on a robot, however, emotion expression by no facial expression but the motion of limbs, LEDs, and audios of a humanoid robot has not been studied for the evaluation of human action decision effect. This study proposes an experiment design based on a finite iterated prisoner's dilemma game with a humanoid robot that shows multimodal emotion expression during the game in order to investigate the effect of the emotion expression of the robot on cooperative and/or selfish action decision making of the human individuals. The experimental results are analyzed to show the influence of the decision making and impression on the robot of the people according to the emotional expression of the humanoid robot.

3:15PM *Black-and-White Drawing support for Adobe Illustrator using Onomatopoeia* [#346]

Yuri Yamada, Gou Kayama, Tsuyoshi Nakamura, Kazuya Endo, Masayoshi Kanoh and Koji Yamada, Nagoya Institute of Technology, Japan; Chukyo University, Japan; Institute of Advanced Media Arts and Sciences, Japan

Adobe Illustrator provides many tools for a user to create art works. The tools also provide many parameters or options that the user can tune up or select. This study focuses on black-and-white drawings ("Sumi-e" or "Suiboku-ga" in Japanese) on Adobe Illustrator. In order to create black-and-white drawings, the user usually has to select a proper brush from preset brushes Adobe Illustrator provides. But the selections are difficult for the user, especially beginners. This paper proposes a supporting plug-in tool for the user to decide and apply the proper brush. The plug-in can accept an onomatopoeic utterance input which expresses the user's own imagination or impression of the brush. Onomatopoeia is well known as a useful figurative expression for Japanese people to describe their own imagination or impression for something. This paper reports the configuration of the plug-in and illustrated some examples of black-and-white drawings created by using the plug-in.

3:30PM *Learning Effect of Robotic Encouragement-based Collaborative Learning* [#96]

Yuhei Tanizaki, Felix Jimenez, Masayoshi Kanoh, Tomohiro Yoshikawa, Takeshi Furuhashi and Tsuyoshi Nakamura, Graduate School of Engineering, Japan; School of Engineering, Japan

With the growth of robot technology, more robots are being designed to support learning. Most studies in the field have focused on robot behavior, with only a few studies focusing on robot utterances. Correspondingly, the manner in which such utterances affect learning is poorly understood. This study investigates the effects of collaborative learning wherein a robot encourages a learner. We conducted an experiment to compare the learning effect in three groups. In the first group, learning was conducted with a robot

that supplied praises using onomatopoeia, i.e., the representation of an object or state based on the sounds associated with it. In the second group, a robot supplied praises using adjectives or adverbs. In the third group, a robot supplied praise without using onomatopoeia, adjectives, or adverbs. The results of this study suggest that collaborative learning using the first or third method is more effective than that involving adjective/adverb communication.

3:45PM *Generating human-like discussion by paraphrasing a translation by the AIWolf Protocol using Werewolf BBS Logs* [#237]

Hirofumi Nakamura, Daisuke Katagami, Fujio Toriumi, Hirotaka Osawa, Michimasa Inaba, Kosuke Shinoda and Yoshinobu Kano, Tokyo Polytechnic University, Japan; The University of Tokyo, Japan; University of Tsukuba, Japan; Hiroshima City University, Japan; The University of Electro-Communications, Japan; Shizuoka University, Japan

"Are you a werewolf?" is one of the most popular communication games and is played globally. The AIWolf Project developed an agent, named "the AIWolf," that can play "Are you a werewolf?". An AIWolf utters its thoughts using an AIWolf Protocol. As it is difficult for humans to understand the AIWolf Protocol, translation into natural language is required when human players are involved. However, the conventional method of translation uses a word-to-word method, creating the impression that the utterances have been generated by a machine. This study aimed make the utterances of AIWolf sound more human. The authors set the target that a human player would be unable to distinguish human speech from that generated by AIWolves (the Turing test). The authors define the situation as the maximum value of humanity. The output of translated AIWolf Protocol was paraphrased using data from Werewolf BBS Logs. This study considers making the utterances of AIWolf sound more human using Werewolf BBS Logs and a possibility assignment equation with fuzzy sets. In this paper, an experiment was conducted to confirm whether paraphrasing the utterances of AIWolf using Werewolf BBS Logs for human-like speech is useful or not. It was shown that the experimental method produced slightly more human-like speech than the conventional method.

Decision modelling under uncertainty. Applications in Economics and Social Sciences and Social Signal Processing-I

Wednesday, July 12, 2:30PM-4:30PM, Room: Santa Lucia, Chair: Gisella Facchinetti and Franco Cutugno

2:30PM *Towards a Fuzzy Volatility Index for the Italian Market* [#104]

Silvia Muzzioli, Luca Gambarelli and Bernard De Baets, University of Modena and Reggio Emilia, Italy; Ghent University, Belgium

The measurement of volatility is of fundamental importance in finance. The standard market practice adopted for the computation of a volatility index imposes to discard some option prices quoted in the market, resulting in a considerable loss of information. To overcome this drawback, we propose to resort to fuzzy regression methods in order to include all the available information and obtain an informative volatility index for the Italian stock market.

2:45PM *Understanding Firms Compensation Policy Using Fuzzy Sets* [#108]

Abdul Suleman, Fatima Suleman and Sergio Lagoa, Instituto Universitario de Lisboa (ISCTE-IUL), Portugal

It has been noted in the literature that firms rarely follow a single theoretical model when designing their compensation policy. This study illustrates how a fuzzy cluster analysis can be helpful in understanding the way employees are

rewarded according to firms' specificity and market conditions. For this purpose, we convert linked employer-employee data (LEED) into firm level data prior to fuzzy clustering. Then, we explore the particular distribution of firms on the emerged fuzzy partition to sort them by compensation policy and, eventually, to examine the potential factors behind a specific option.

3:00PM *Hypothesis Test for Identifying the Vague Factors from Consolidated Income* [#112]

Pei-Chun Lin, Nureize Arbaiy and Yung-Chin Hsiao, Department of Information Engineering and Computer Science, Feng Chia University, Taiwan; Faculty of Computer Science and Information Technology, University Tun Hussein Onn Malaysia, Malaysia; Graduate School of Information, Production and Systems, Waseda University, Japan

This study proposes a statistical hypothesis test with fuzzy data which is represented in a form of interval data to perform one-way analysis of variance (ANOVA) test with fuzzy data. We adopt 2015 LEGO consolidated income as an empirical study for analyzing the main factors that affecting the LEGO annual profit by using one-way ANOVA Test with interval data. The results shown that each impact factor has different influence levels by means of testing their means. To confirm the most influential impact factor of 2015

LEGO annual profit, we provided the pair-wise comparisons in the evaluation. The comparison results shown that the greater financial income is decided from revenue factor and the most risk will be revealed from expenses factor. We concluded that the proposed method is able to assist an enterprise in identifying the main impact factors which are crucial for financial decision making.

3:15PM *New Approach to Measure Preference Stability* [#129]

Teresa Gonzalez-Arteaga and Rocio de Andres Calle, University of Valladolid, Spain; University of Salamanca, Spain

A non-traditional approach about the measurement of agents' preference stability is introduced. This contribution focus on measuring preference consensus at different moments under the assumption of considering the following evaluations: approved, undecided and disapproved. To this aim, the concept of preference stability measure is defined as well as a particular one, the sequential preference stability measure, taking into account any two successive time moments. Finally and in order to highlight the good behaviour of novel measures, some properties are also provided.

3:30PM *Credit Risk Profiling using a new evaluation of Interval-Valued Fuzzy Sets based on alpha-cuts* [#358]

Luca Anzilli, Gisella Facchinetti and Tommaso Pirotti, University of Salento, Italy

In this paper we propose a parametric way to associate to an interval-valued fuzzy set its evaluation useful for its ranking. The novelty of this paper is connected with the fact that we follow a line based on its alpha-cuts and the parametric formulation we obtain, leaves to the decision maker a wide freedom. For particular values of these parameters we obtain Nie and Tan defuzzification method that, in its classical definition, shows only the evaluation, but looking at it in this new version we obtain further information. The proposed methodology is then applied to risk profiling of a bank client using an interval type-2 fuzzy logic system.

3:45PM *Optimization of Dynamic Maximum for Value-at-Risks with Fuzziness in Asset Management* [#68]

Yuji Yoshida, University of Kitakyushu, Japan

A dynamic portfolio allocation is discussed in asset management with fuzziness. By perception-based extension for fuzzy random variables, a dynamic portfolio model for value-at-risks of fuzzy random variables is introduced. By dynamic programming and mathematical programming, this paper derives analytical solutions for the optimization problem. A numerical example is given to demonstrate the results.

Complex Fuzzy Sets and Logic

Wednesday, July 12, 2:30PM-4:30PM, Room: Catalana, Chair: Sarah Greenfield, Francisco Chiclana, Scott Dick

2:30PM *Complex Neutrosophic Soft Set* [#65]

Said Broumi, Assia Bakali, Mohamed Talea, Florentin Smarandache, Ali Mumtaz and Selvachandran Ganeshsree, Laboratory of Information processing, Faculty of Science Ben M'Sik, Morocco; Ecole Royale Navale, Boulevard Sour Jdid, Morocco; University of New Mexico, United States; University of Southern Queensland 4300, QLD Australia, Australia; UCSI University, Malaysia

In this paper, we propose the complex neutrosophic soft set model, which is a hybrid of complex fuzzy sets, neutrosophic sets and soft sets. The basic set theoretic operations and some concepts related to the structure of this model are introduced, and illustrated. An example related to a decision making problem involving uncertain and subjective information is presented, to demonstrate the utility of this model.

2:45PM *Using Complex Fuzzy Sets for Strategic Cost Evaluation in Supply Chain Downstream* [#111]

Jun Ma, Lipeng Feng and Jie Yang, SMART Infrastructure Facility, University of Wollongong, Australia

Cross-border E-commerce has grown exponentially in the past decade. To gain global competitiveness in product-convergent markets, China's over 200 thousands cross-border E-commerce businesses have focused more on the service and cost of supply chain downstream. Therefore, selecting appropriate cost control strategy has marked impact on them. In this study, we evaluated three strategic cost control measures according to 10 evaluation criteria by using a complex fuzzy set based model, named C-COPRAS. The C-COPRAS model is an extension of the COMplex PROportion ASessment (COPRAS) method. This model uses complex fuzzy set to tackle uncertainty and temporal features in given evaluation context. We then apply this model to a case study of helping a Chinese E-commerce

business to select strategic cost control measure on supply chain downstream.

3:00PM *Set Operations on Maxitive Belief Structures* [#320]

Lei Li, Xintao Hu and Yongming Li, Northwestern Polytechnical University, China; Shaanxi Normal University, China

This paper studies the set operations on maxitive belief structures, which introduced by Yager and Alajlan as a framework for modeling imprecise possibility distributions. Unlike Dempster-Shafer structures, we show that different maxitive belief structures can induce the same upper and lower possibilities. Then the operations on maxitive belief structures might not be the operations on their induced upper and lower possibilities. We call those operations on maxitive belief structures which are also the operations on their induced upper and lower possibilities the nice operations. We introduce the set operations on maxitive belief structures, including weighted sum, intersection, union, complement, projection, cylindrical extension and Cartesian product operations. We show that the weighted sum, union, projection and cylindrical extension are nice operations, and the intersection, complement and Cartesian product operations are not nice.

3:15PM *Inductive Learning of Classifiers via Complex Fuzzy Sets and Logic* [#483]

Mojtaba Yeganejou and Scott Dick, University of Alberta, Canada

Multiple studies have shown that time series forecasting algorithms based on complex fuzzy sets and logic can be both very accurate, and simultaneously very compact. There have as yet, however, been no corresponding studies of time series classification, even though it seems reasonable that similar advantages would be obtained. We propose an inductive learning architecture for time series classification based on complex fuzzy sets and logic. We evaluate this new architecture on a condition monitoring problem: detecting the onset of illness in feedlot cattle via

animal-mounted sensors. We find that our new system is at least as accurate as existing approaches.

3:30PM *Towards attribute reduction in object-oriented concept lattices* [#493]

Jesus Medina and Eloisa Ramirez-Poussa, University of Cadiz, Spain

Attribute reduction is an important issue in different frameworks. Formal concept analysis (FCA) and object-oriented concept lattices (which is a generalization of rough sets) have been related in different papers. This contribution studies the attribute reduction in object-oriented concept lattices from the one recently given in FCA. As a consequence, we have proven that the study of the classification of the attributes in absolutely necessary, relatively necessary and unnecessary attributes is equivalent in both frameworks. An illustrative example has also been introduced.

3:45PM *Bipolar Fuzzy Relation Equations based on the Product T-norm* [#488]

Maria Eugenia Cornejo, David Lobo and Jesus Medina, University of Cadiz, Spain

Bipolar fuzzy relation equations are given from the fuzzy relation equations introduced by Sanchez in the 1980s considering a negation operator in the equations. Numerous applications require variables that show a bipolar character such as decision making and revenue management, hence the importance of studying bipolar fuzzy relation equations. According to the literature, bipolar max-min equations have already been studied and a characterization of their solutions, by means of a finite set of maximal and minimal solution pairs, has been provided. This paper will present a first study on bipolar max-product fuzzy relation equations with one equation containing different variables, which includes different interesting properties in order to guarantee both their solvability and the existence of the greatest (least) solution or maximal (minimal) solutions. Moreover, a characterization of the solvability of a particular system of two bipolar max-product fuzzy relation equations is given.

Rough sets and Fuzzy Rough Hybridization with bioinspired optimization

Wednesday, July 12, 2:30PM-4:30PM, Room: Giardino, Chair: Vladik Kreinovich, Camelia Pintea
Ahmad Taher Azar

2:30PM *Nonlinear Classification, Linear Clustering, Evolutionary Semi-Supervised Three-Way Decisions: A Comparison* [#132]

Matt Triff, Glavin Wiechert and Pawan Lingras, Saint Mary's University, Canada

This paper compares the semantically meaningful machine learning algorithms with the black box models. The machine learning models are applied to a real world wearable dataset for biometric identification of individuals. The semantically meaningful decision tree is compared with more accurate black-box models such as neural networks, random forest, and support vector machines. The paper further explores the possibility of using unsupervised learning that uses linear distances for separating the categories. Since the distance from the center is used to delineate the clusters, the centroids of the unsupervised clusters provide a semantic profile of the categories. The crisp K-means clustering is enhanced with evolutionary algorithms that primarily uses the distance from the center as the primary criteria, but nudges the clustering towards known classification using a semi-supervised penalty. Finally, the use of rough sets is shown to provide notable semantic information with the help of the three-way decision principle.

2:45PM *Fuzzy Rough Feature Selection Based on OWA Aggregation of Fuzzy Relations* [#179]

Pan Su, Changjing Shang, Yitian Zhao, Tianhua Chen and Qiang Shen, School of Control and Computer Engineering, North China Electric Power University, Baoding, China, China; Department of Computer Science, Institute of Mathematics, Physics and Computer Science Aberystwyth University, Aberystwyth, UK, United Kingdom; Beijing Engineering Research Center of Mixed Reality and Advanced Display, School of Optics and Electronics, Beijing Institute of Technology, Beijing, China, China

The interaction between features, or attributes, of a dataset forms a major topic in machine learning and data mining. In particular, a wide range of methods have been established for feature selection, ranking, and grouping. Amongst these, fuzzy rough set based feature selection (FRFS) has been shown to be highly effective at reducing dimensionality for real-valued datasets while retaining attribute semantics. In fuzzy rough sets, the concept of crisp equivalence classes is extended by fuzzy similarity relations, and real-valued similarity measures can be captured between data instances in terms of their attribute values. Therefore, it is desirable to study the aggregation of fuzzy similarity relations to reflect the interactions between attributes. This paper presents an approach that employs OWA aggregation of fuzzy similarity relations to better perform FRFS. A high degree of modelling flexibility is provided by choosing the stress function in OWA. Experimental studies demonstrate that through using different stress functions, different features may be selected; and that given an appropriate stress function, the quality of selected features can improve over that achievable by the state-of-the-art FRFS, in performing classification tasks.

DM V: Fuzzy Linguistic Decision Making

Wednesday, July 12, 2:30PM-4:30PM, Room: Borbonica, Chair: Luis Martínez Enrique Herrera-Viedma

2:30PM *Combined QFD TOPSIS Approach with 2-Tuple Linguistic Information for Warehouse Selection* [#479]

Gulcin Buyukozkan and Deniz Uzturk, Galatasaray University, Turkey

2-tuple fuzzy linguistic model can be applied to eliminate vagueness/uncertainty in information. It also helps to deal with non-homogeneous information that occurs during group decision making (GDM) processes. GDM is generally applied to diminish the bias during the decision phase and to reduce the subjectivity of the decision process. Thus, this paper proposes an integrated GDM technique based on 2-tuple linguistic model, quality function deployment (QFD) and the Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) method. This proposed framework is then applied to a green warehouse selection problem. The originality of this paper comes from its combination of these two methodologies together for the first time in literature in this specific field. The application area indicates its suitability for the proposed methodology.

2:45PM *A TODIM-Based Approach to Large-Scale Group Decision Making with Multi-Granular Unbalanced Linguistic Information* [#289]

Yu Wen-Yu, Zhang Zhen and Zhong Qiu-Yan, Dalian University of Technology, China

Large-scale group decision making problems exist widely in human being's daily life. In this paper, a new approach to large-scale multi-attribute group decision making with multi-granular unbalanced linguistic information is developed. First, an algorithm is proposed to represent the initial multi-granular unbalanced linguistic information of decision makers with the use of unbalanced linguistic distribution assessments. Based on the gain and loss of an unbalanced linguistic distribution assessment over another, the classical TODIM (an acronym in Portuguese of interactive and multiple attribute decision making) method is then extended to derive a ranking of alternatives for large-scale multi-attribute group decision making problems. Finally, an example for talent selection is used to demonstrate the feasibility of the proposed approach.

3:00PM *Multi-objective Linguistic optimization: extensions and new directions using 2-tuple fuzzy linguistic representation model* [#617]

Prashant Gupta and Pranab Muhuri, South Asian University, India

Multi objective linguistic optimization is a useful mathematical technique to solve problems that interdependent criteria. In such problems, values of the objective functions may be unknown at some points, when the link between the variables and the objective functions are defined linguistically through if-then rules. While solving this type of problems, Tsukamoto based reasoning method has proved useful for converting objective function to a crisp form, and then using the resulting objective function to solve by any traditional optimization technique. However, this method suffers from a drawback that the resulting solution is in numeric form whereas it should have been in linguistic form, owing to the linguistic definition of if-then rules. So, here we propose 2-tuple fuzzy linguistic representation model based method for solving the Multi objective linguistic optimization problem. We demonstrate the novelty of our approach through a suitable example. We also prove that the proposed approach generates unique recommendation in linguistic form.

3:15PM *Evaluating student-internship fit using fuzzy linguistic terms and a fuzzy OWA operator* [#425]

Jennifer Nguyen, German Sanchez-Hernandez, Nuria Agell, Albert Armisen, Xari Rovira and Cecilio Angulo, Universitat Politècnica de Catalunya, Spain; ESADE Business School, Ramon Llull University, Spain

Personnel selection is a well-known problem that is made difficult by incomplete and imprecise information about candidate and position compatibility. This paper shows how positions, which satisfy candidate's interests, can be identified with fuzzy linguistic terms and a fuzzy OWA operator. A set of relevant positions aligned with a student's interests is selected using this approach. The implementation of the proposed method is illustrated using a numerical example in a business application.

3:30PM *Strategic Weight Manipulation in Multiple Attribute Decision Making in an Incomplete Information Context* [#66]

Yating Liu, Yucheng Dong, Francisco Chiclana, Francisco Javier Cabrerizo and Enrique Herrera-Viedma, Business School, Sichuan University, Chengdu, China; Centre for Computational Intelligence, De Montfort University, Leicester, United Kingdom; DECSAI, University of Granada, Granada, Spain

In some real-world multiple attribute decision making (MADM) problems, a decision maker can strategically set attribute weights to obtain her/his desired ranking of alternatives, which is called the strategic weight manipulation of the MADM. Sometimes, the attribute weights are given with imprecise or partial information, which is called incomplete information of attribute weights. In this study, we propose the strategic weight manipulation under incomplete information on attributes weights. Then, a series of mixed 0-1 linear programming models (MLPMs) are proposed to derive a strategic weight vector for a desired ranking of an alternative. Finally, a numerical example is used to demonstrate the validity of our models

3:45PM *Online Peer Marking with Aggregation Functions* [#337]

Simon James, Lei Pan, Tim Wilkin and Lilin Yin, Deakin University, Australia

With the rise of Massive Open Online Courses (MOOCs), online peer marking is an attractive contemporary tool for educational assessment. However its widespread use faces serious challenges, most significantly in the perceived and actual reliability of assessment grades, which can be affected by the ability of peers to mark accurately and the potential for collusion and bias. There exist a number of aggregation approaches for alleviating the impact of biased scores, usually involving either the down-weighting or removal of outliers. Here we investigate the use of the least trimmed squares (LTS) and Huber mean for the aggregation step, comparing their performance to weighting of markers based on divergence from other peers' marks. We design an experimental setup to generate scores and test a number of conditions. Overall we find that for a feasible number of peer markers, when the student pool comprises a significant number of 'biased' markers, outlier removal techniques are likely to result in a number of very unfair assessments, while more standard approaches will have more grades unfairly influenced but to a lesser extent.

Fuzzy Data Science I

Wednesday, July 12, 2:30PM-4:30PM, Room: Auditorium, Chair: Francesco Marcelloni

2:30PM *Soft Querying of Sensorial Data* [#43]

Cecile Coulon-Leroy and Ludovic Lietard, Ecole Supérieure d'Agricultures (ESA)-INRA, France; IRISA/ENSSAT, France

Data of a sensory profile represent human's evaluations and feelings about intensities of several criterias to describe and compare different products (as the criteria odor of red fruits for a red wine). This article concerns the representation and querying of such data. It is shown that sensorial data are intrinsically imprecise due to this human evaluation (possibilistic data), and especially for untrained people. The data treatment can take advantages of a querying with user's preferences (flexible querying with fuzzy predicates). The classical approach to evaluate a fuzzy predicate on a possibility distribution is based on a possibility and a necessity measures of a fuzzy event and it is shown that this approach may be not convenient. A new expression for the evaluation of a fuzzy predicate on a possibility distribution is then introduced. More complex flexible queries on possibilistic data are defined and methods to rank the answers are also proposed.

2:45PM *Building and Evaluation of Indexes for Possibilistic Queries on a Fuzzy Object-Relational Database Management System* [#47]

Juan Miguel Medina, Carlos D. Barranco, Olga Pons and Daniel Sanchez, Granada University, Spain; Pablo de Olavide University, Spain

An effective way to implement a fuzzy database is on top of a classical Relational Database Management Systems (RDBMS). In this sense, we have proposed a Fuzzy Object Relational Database Management System (FORDBMS) built on top of Oracle RDBMS. To enhance the performance of queries based on possibility, we have carried out a study to adapt indexing techniques available in classical RDBMS to the fuzzy retrieval. This paper shows the implementation of the best of these indexing techniques on our FORDBMS and evaluates and compares their performance. The results show that the best of these techniques enhance query execution time in several orders of magnitude with respect to sequential retrieving.

3:00PM *Robust Extreme Learning Fuzzy Systems Using Ridge Regression for Small and Noisy Datasets* [#64]

Te Zhang, Zhaohong Deng, Kup-Sze Choi, Jiefang Liu and Shitong Wang, School of Digital Media, Jiangnan University, Wuxi, Jiangsu, P.R. China, China; Centre for Smart Health, Hong Kong Polytechnic University, Hong Kong, China

Fuzzy Extreme Learning Machine (F-ELM) constructs a fuzzy neural networks by embedding fuzzy membership functions and rules into the hidden layer of extreme learning machine (ELM), that is, it can be interpreted as a fuzzy system with the structure of neural network. Although F-ELM has shown the characteristics of fast learning of model parameters, it has poor robustness to small and noisy datasets since its parameters connecting hidden layer with output layer are optimized by least square (LS). In order to overcome this challenge, a Ridge Regression based Extreme Learning Fuzzy System (RR-EL-FS) is presented in this study, which has introduced the strategy of ridge regression into F-ELM to enhance the robustness. The experimental results also validate that the performance of RR-EL-FS is better than F-ELM and some related methods to small and noisy datasets.

3:15PM *Handling Failing Queries Over Uncertain Databases* [#145]

Chourouk Belheouane, Stephane Jean, Allel Hadjali and Hamid Azzoune, LRIA - USTHB, Algiers, Algeria; LIAS/ISAE-ENSMA - University of Poitiers, France; Lria - Usthb, Algiers, Algeria

A large number of applications manage uncertain data. Usually, users expect high quality results when they pose queries with strict conditions over these data. However, as they may not be clear about the contents of the databases that contain such data, these queries may be failing i.e., they may return no result or results that do not satisfy the expected degree of certainty. In this paper, we deal with this problem by proposing an approach that identifies the parts of the failing query, called Minimal Failing Subqueries (MFSs), that are responsible of its failure. Our approach also computes, in the same time, a set of Maximal Succeeding Subqueries (XSSs) that represent non failing queries with a maximal number of predicates of the initial query. We demonstrate the impact of our proposal with a set of experiments on synthetic and real datasets.

3:30PM *The Arithmetic Recursive Average as an Instance of the Recursive Weighted Power Mean* [#191]

Christian Wagner, Timothy C Havens and Derek T Anderson, Michigan Technological University, University of Nottingham, United Kingdom; Michigan Technological University, United States; Mississippi State University, United States

The aggregation of multiple information sources has a long history and ranges from sensor fusion to the aggregation of individual algorithm outputs and human knowledge. A popular approach to achieve such aggregation is the fuzzy integral (FI) which is defined with respect to a fuzzy measure (FM) (i.e. a normal, monotone capacity). In practice, the discrete FI aggregates information contributed by a discrete number of sources through a weighted aggregation (post-sorting), where the weights are captured by a FM that models the typically subjective 'worth' of subsets of the overall set of sources. While the combination of FI and FM has been very successful, challenges remain both in regards to the behavior of the resulting aggregation operators—which for example do not produce symmetrically mirrored outputs for symmetrically mirrored inputs—and also in a manifest difference between the intuitive interpretation of a stand-alone FM and its actual role and impact when used as part of information fusion with a FI. This paper elucidates these challenges and introduces a novel family of recursive average (RAV) operators as an alternative to the FI in aggregation with respect to a FM; focusing specifically on the arithmetic recursive average. The RAV is designed to address the above challenges, while also facilitating fine-grained analysis of the resulting aggregation of different combinations of sources. We provide the mathematical foundations of the RAV and include initial experiments and comparisons to the FI for both numeric and interval-valued data.

3:45PM *On Various Types of Controlled-sized Clustering Based on Optimization* [#259]

Yasunori Endo, Sachiko Ishida, Naohiko Kinoshita and Yukihiro Hamasuna, University of Tsukuba, Japan; Kindai University, Japan

Clustering is one of unsupervised classification method. Typical clustering methods are constructed based on optimization of the given objective function. Many clustering methods are formulated as optimization problems

with typical objective functions and constraints. The objective function itself is also an evaluation guideline of results of clustering methods. Considered together with its theoretical extensibility, there is the great advantage to construct clustering methods in the framework of optimization. From the viewpoint of optimization, some of the authors proposed an Even-sized Clustering method Based on Optimization (ECBO), which is with tight constraints of cluster size, and constructed some variations of ECBO. It is considered that ECBO has the advantage in the viewpoint of clustering accuracy, cluster size, and optimization framework than other similar methods. However, the constraint of cluster sizes of ECBO is tight in the meaning of cluster size so that it may be inconvenient in case that some

extra margin of cluster size is allowed. Moreover, it is expected that new clustering algorithms in which each cluster size can be controlled deal with more various datasets. From the above view point, we proposed two new clustering algorithms based on ECBO. One is COntrolled-sized Clustering Based on Optimization (COCBO), and the other is an extended COCBO, which is referred to as COntrolled-sized Clustering Based on Optimization++ (COCBO++). Each cluster size can be controlled in the algorithms. However, these algorithms have some problems. In this paper, we will describe various types of COCBO to solve the above problems and estimate the methods in some numerical examples.

Wednesday, July 12, 5:00PM-7:00PM

Fuzzy Logic Applications

Wednesday, July 12, 5:00PM-7:00PM, Room: Normanna, Chair: Nikhil Pal Alfredo Vaccaro, and Sansanee Auephanwiriyakul

5:00PM *FuzzyDES or How DES Met Bousi-Prolog* [#294]

Julian-Iranzo Pascual and Saenz-Perez Fernando, University of Castilla-La Mancha, Spain; Universidad Complutense de Madrid, Spain

This article describes the implementation of the fuzzy deductive database system FuzzyDES, where concepts underlying the fuzzy logic programming system Bousi-Prolog are adapted and improved to be transferred to the DES deductive database system. We take advantage of the DES table-based implementation to propose new methods for rule compiling and t-closure computing, developing a terminating query answering system with graded rules. A description of the system, an example, and a link to a publicly-available, comprehensive system are provided.

5:15PM *A New Learning Approach for Takagi-Sugeno Fuzzy Systems Applied to Time Series Prediction* [#538]

Rosa Altilio, Antonello Rosato and Massimo Panella, DIET - University of Rome "La Sapienza", Italy

In this paper, we present a study on the use of fuzzy neural networks and their application to the prediction of times series generated by complex processes of the real-world. The new learning strategy is suited to any fuzzy inference model, especially in the case of higher-order Sugeno-type fuzzy rules. The data considered herein are real-world cases concerning chaotic benchmarks as well as environmental time series. The comparison with respect to well-known neural and fuzzy neural models will prove that our approach is able to follow the behavior of the underlying, unknown process with a good prediction of the observed time series.

5:30PM *Selecting Cloud Computing Service Provider with Fuzzy AHP* [#474]

Neda Tanoumand, Dicle Yagmur Ozdemir, Kemal Kilic and Faran Ahmed, Sabanci University, Turkey

Cloud Computing (CC) service providers are becoming more popular as the demand for outsourcing information and communication technology (ICT) section of enterprises has increased. Selecting the most appropriate service provider for an enterprise depends on various criteria that are based on the strategies, requirements, and resources of the enterprise. Since this decision problem is dependent on various conflicting criteria and a decision-maker has to choose the best alternative while satisfying these criteria; therefore, it can be modeled as a Multi-criteria Decision Making (MCDM) problem. In this research, a pilot case study is conducted in which the CC service provider selection problem is modeled as a MCDM problem and Fuzzy Analytical Hierarchical Process (FAHP) which is the most widely used methodology in

the domain of MCDM, is implemented to select the most appropriate service provider.

5:45PM *Monotone Data Samples Do Not Always Produce Monotone Fuzzy If-Then Rules: Learning with Ad hoc and System Identification Methods* [#22]

Chin Ying Teh, Kai Meng Tay and Chee Peng Lim, Universiti Malaysia Sarawak, Malaysia; Deakin University, Australia

In this paper, ad hoc and system identification methods are used to generate fuzzy If-Then rules for a zero-order Takagi-Sugeno-Kang (TSK) Fuzzy Inference System (FIS) using a set of multi-attribute monotone data. Convex and normal trapezoidal fuzzy sets, with a strong fuzzy partition strategy, is employed. Our analysis shows that even with multi-attribute monotone data, non-monotone fuzzy If-Then rules can be produced using an ad hoc method. The same observation can be made, empirically, using a system identification method, e.g., a derivative-based optimization method and the genetic algorithm. This finding is important for modeling a monotone FIS model, as the result shows that even with a "clean" data set pertaining to a monotone system, the generated fuzzy If-Then rules may need to be pre-processed, before being used for FIS modeling. As such, monotone fuzzy rule relabeling is useful. Besides that, a constrained non-linear programming method for FIS modelling is suggested, as a variant of the system identification method.

6:00PM *Fuzzy Clustering Methods Applied to the Evaluation of Compost Bedded Pack Barns* [#87]

Vania Mota, Flavio Damasceno, Eduardo Soares and Daniel Leite, Dept. of Engineering - Federal University of Lavras (UFLA), Brazil

This paper concerns the application of fuzzy clustering methods in the evaluation of compost bedded pack (CBP) barns. Fuzzy classifiers are developed to assist decision making regarding the control of associated variables such as bed moisture, temperature and aeration. The idea is to promote dairy cattle welfare and therefore improve productivity indices. The data was obtained from CBP barns in the state of Kentucky, US. Details about the data acquisition methodology are given. Well-known clustering methods, namely K-Means (KM), Fuzzy C-Means (FCM), Gustafson-Kessel (GK), and Gath-Geva (GG), are considered for data analysis. The efficiency of the methods is determined by validation indices such as the Xie-Beni criterion, Partition Coefficient, and Partition and Dunn indices. Six classes were identified in the data; they are related to the degree of efficiency of the composting process, where efficiency means stability, maturity and activeness of the compost, and ideal bacterial concentration in the bed. The GG method showed to be the most accurate method according to the

majority of the validation indices, followed by the GK method. The main reason for the best results is the use of maximum-likelihood-based and Mahalanobis distance measures instead of Euclidean measure. Fuzzy modeling results and linguistic information have shown to be useful to help decision making in farms that adopt CBP barns as containment systems for dairy cattle.

6:15PM *Fuzzy vectorial-based similarity detection of Music Plagiarism* [#438]

Roberto De Prisco, Delfina Malandrino, Gianluca Zaccagnino and Rocco Zaccagnino, University of Salerno, Italy

Plagiarism, i.e., copying the work of others and trying to pass it off as one own, is a debated topic in different fields. In particular, in music field, the plagiarism is a controversial and debated phenomenon that has to do with the huge amount of money that music is able to generate. However, the

existing mechanisms for plagiarism detection mainly apply superficial and brute-force string matching techniques. Such well-known metrics, widely used to discover similarities in text documents, cannot work well in discovering similarities in music compositions. Despite the wide-spread belief that few notes in common between two songs is enough to decide whether a plagiarism exists, the analysis of similarities is a very complex process. In this work, we provide novel perspectives in the field of automatic music plagiarism detection, and specifically, we propose an approach based on a fuzzy vectorial-based similarity. Given a suspicious melody, our approach envisions three steps: (1) its transformation in a vectorial representation, (2) retrieving of a list of similar melodies, (3) analysis and comparison with this subset of associated similar scores by using a fuzzy degree of similarity, that varies in a range between 0 for melodies that are fully musically different, and 1 for identical melodies. To assess the effectiveness of our system we performed tests on a large dataset of ascertained plagiarisms. Results show that it is able to reach an accuracy of 93%.

Fuzzy Logic in Autonomous Robots

Wednesday, July 12, 5:00PM-7:00PM, Room: Sveva, Chair: Alberto Finzi Fanny Ficuciello and Silvia Rossi

5:00PM *A Comparison of Fuzzy Approaches for Training a Humanoid Robotic Football Player* [#593]

Giovanni Acampora, Alessandro Di Nuovo, Bruno Siciliano and Autilia Vitiello, University of Naples Federico II, Italy; Sheffield Hallam University, United Kingdom; University of Salerno, Italy

Fuzzy Systems are an efficient instrument to create efficient and transparent models of the behavior of complex dynamic systems such as autonomous humanoid robots. The human interpretability of these models is particularly significant when it is applied to the cognitive robotics research, in which the models are designed to study the behaviors and produce a better understanding of the underlying processes of the cognitive development. From this research point of view, this paper presents a comparative study on training fuzzy based system to control the autonomous navigation and task execution of a humanoid robot controlled in a soccer scenario. Examples of sensor data are collected via a computer simulation, then we compare the performance of several fuzzy algorithms able to learn and optimize the humanoid robot's actions from the data

5:15PM *Interpreting Fuzzy Directional Information in Navigational Commands Based on Arrangement of the Surrounding Environment* [#241]

M. A. Viraj J. Muthugala and A. G. Buddhika P. Jayasekara, University of Moratuwa, Sri Lanka

Human friendly service robots should possess human like interaction and reasoning capabilities. Humans prefer to use voice instructions in order to communicate with peers. Those voice instructions often include linguistic notions and descriptors that are fuzzy in nature. Therefore, the human friendly robots should be capable of understanding the fuzzy information in user instructions. This paper proposes a method in order to interpret directional information in navigational user commands by considering the environment dependent fuzziness associated with the directional linguistic notions. A module called Direction Interpreter has been introduced for handling the fuzzy nature of directional linguistic notions. The module has been implemented with a fuzzy logic system that is capable of modifying the

perception of the robot about the directional information according to the surrounding environment of the robot. This modification is done by weighting the output membership function with the distribution of the free space around the robot. According to the experimental results, the proposed system is capable of replicating the natural directional perception of humans that depends on the environment to a greater extent than the existing approaches.

5:30PM *Interpretation of Interaction Demanding of a User Based on Nonverbal Behavior in a Domestic Environment* [#355]

Chapa Sirithunge, Viraj Muthugala, Buddhika Jayasekara and Chandima Pathirana, University of Moratuwa, Sri Lanka

Human-robot interaction mechanisms are being developed to cater to growing elderly and disabled population. There are still voids in achieving human-likeness before initiation of an interaction. Interaction scenario could be made interesting and effective by engraving basic cognitive skills into the robot's intelligence. Skills related to human-like interaction depends on cognitive skills and interpretation of the existing situation. Most robot users encounter a common problem with their robots. That is robot trying to interact with the user when he's engaged. In robot's perspective, the robot is not fully capable of deciding when to interact with the user. This paper presents a model to decide when to interact with the user, minimizing such failures. The proposed model has separate functional units for decision making on a user's nonverbal interaction demanding. User's availability for interaction is deduced through extracted information. The system observes a user for his bodily movements and behavior for a specified time duration. The extracted information is analyzed and then put through a module called Interaction Demanding Pose Identifier to interpret the interaction demanding of the user. The identified pose and other calculated parameters are fed into the Fuzzy Interaction Decision Making Module in order to interpret the degree of interaction demanding of the user. Interaction demanding is taken into consideration before going for direct interaction with the user. This method is implemented and tested in a simulated domestic environment with users in a broad age gap. Implementation of the method and results of the experiment are presented.

5:45PM *Long distance prediction and short distance control in Human-Robot Systems* [#39]

Rainer Palm and Achim J. Lilienthal, Oerebro University, Sweden

The study of the interaction between autonomous robots and human agents in common working areas is an emerging field of research. Main points thereby are human safety, system stability, performance and optimality of the

whole interaction process. Two approaches to deal with human-robot interaction can be distinguished: Long distance prediction which requires the recognition of intentions of other agents, and short distance control which deals with actions and reactions between agents and mutual reactive control of their motions and behaviors. In this context obstacle avoidance plays a prominent role. In this paper long distance prediction is represented by the identification of human intentions to use specific lanes by using fuzzy time clustering of pedestrian tracks. Another issue is the extrapolation of parts of both human and robot trajectories in the presence of scattered/uncertain measurements to guarantee a collision-free robot motion. Short distance control is represented by obstacle avoidance between agents using the method of velocity obstacles and both analytical and fuzzy control methods.

6:00PM *A Neuro-Fuzzy-Bayesian Approach for the Adaptive Control of Robot Proxemics Behavior* [#426]
Autilia Vitiello, Giovanni Acampora, Mariacarla Staffa, Bruno Siciliano and Silvia Rossi, Department of Computer Science, University of Salerno, Italy; Department of Physics "Ettore Pancini", University of Naples Federico II, Italy; Department of Computer Science and Biomedical Engineering, Parthenope University of Naples, Italy; Department of Electrical Engineering and Information Technology, University of Naples Federico II, Italy

A robotic system that is designed to coexist with humans has to adapt its behavioral and social interaction parameters not only with respect to the task

it is supposed to accomplish, but also with respect to the human being it is interacting with by profiling her habits, preferences, and personality. This is particularly relevant in the domain of assistive robotics where the behavioral adaptability has been shown to enhance the users' acceptability of a robot. In this work, we propose a neuro-fuzzy-bayesian system able to adapt the robot proxemics behavior with respect to the human users' personality and the action she is currently performing. The user's personality is evaluated according to the Big-Five factors model and the activity recognition is obtained by classifying data from a wearable device through the use of a Bayesian Network classifier. As shown by a statistical study, the proposed framework is capable of computing the most appropriate robot proxemics behavior in order to improve human feeling in interacting with artificial agents, such as robots.

Decision modelling under uncertainty. Applications in Economics and Social Sciences and Social Signal Processing-II

Wednesday, July 12, 5:00PM-7:00PM, Room: Santa Lucia, Chair: Inés Couso Gisella Facchinetti and Bice Cavallo

5:00PM *A fuzzy graph multi-mode approach to modelling and solving scheduling problem with limited resources* [#302]

Alexander Bozhenyuk, Margarita Knyazeva and Igor Rozenberg, Southern Federal University, Russian Federation; Public corporation "Research and development institute of railway engineers", Russian Federation

This paper reports on a graph-based approach to modelling and solving combinatorial resource-constrained scheduling problem with respect to possibility to perform the individual activities in alternative ways (modes). These modes vary depending on processing time, time lags to other activities and resource requirements. A fuzzy scheduling problem can be formally defined by a number of activities-nodes that should be scheduled to minimize the project duration subject to generalized precedence relations, may require some units of limited in time use resources. Solution methodology is based on branch and bound procedure to operate with resource requirements and precedence constraints as well as selection of one single activity mode to construct a schedule.

5:15PM *Interval fuzzy rule-based modeling approach for financial time series forecasting* [#435]

Leandro Maciel and Rosangela Ballini, Federal University of Rio de Janeiro, Brazil; University of Campinas, Brazil

Financial interval time series (ITS) describe the evolution of the maximum and minimum prices of an asset throughout time, which can be related to the concept of volatility. Hence, their accurate forecasts play a key role in risk management, derivatives pricing and asset allocation, as well as supplements the information extracted by the time series of the closing price

values. This paper proposes an interval fuzzy rule-based model (iFRB) for ITS forecasting. iFRB consists in a fuzzy rule-based approach with affine consequents, which provides a nonlinear method that processes interval-valued data. It is suggested as empirical application the prediction of the main index of the Brazilian stock market, the IBOVESPA. One-step-ahead interval forecasts are compared against traditional univariate and multivariate time series benchmarks and with an interval multilayer perceptron neural network in terms of accuracy metrics and statistical tests. The results indicate that iFRB provides accurate forecasts and appears as a potential tool for financial ITS forecasting.

5:30PM *A new approach to linear programming with interval costs* [#447]

Maria Letizia Guerra, Laerte Sorini and Luciano Stefanini, University of Bologna, Italy; University of Urbino, Italy

Linear Programming problems are solved in the present paper when costs are interval numbers and the comparison index based on the generalized Hukuhara difference is adopted to suggest the choice between two intervals that may have all the possible relative positions.

5:45PM *Fuzzy Analytic Network Process for evaluating ERP post-implementation alternatives* [#92]

Jonghyeon Ko and Marco Comuzzi, Ulsan National Institute of Science and Technology, Korea (South)

Because of the unreliability of human experts judgements, fuzzy systems are widely applied in decision making problems related to adoption, implementation and maintenance of ERP systems. This paper presents a novel application of the fuzzy Analytical Network Process (ANP) for evaluating ERP post-implementation alternatives. The proposed framework aims at ranking different alternatives to implement a given post-implementation business requirement based on experts perception of

implementation effort and risk. Regarding decision criteria, the ANP network considers two main levels. At the higher level we consider technical effort, organisational effort and long-term risk, whereas at the lower level we consider different strategies for implementing given business objects, functions and processes in an existing ERP system. Decision makers preferences are translated into preference weights using triangular fuzzy numbers. An example loosely based on a case study in a semiconductor company is presented to show the application of the proposed framework.

6:00PM *A Social Choice Approach to Graded Soft Sets* [#79]

Fatia Fatimah, Dedi Rosadi, RB Fajriya Hakim and Jose Alcantud, Universitas Terbuka, Indonesia; Universitas Gadjah Mada, Indonesia; Universitas Islam Indonesia, Indonesia; University of Salamanca, Spain

We establish a correspondence between ideas from soft computing and social choice. This connection permits to draw bridges between choice mechanisms as well. Therefore we lay the grounds for new insights into soft-set-inspired decision making with a social choice foundation.

Recent trends in many-valued logic and fuzziness

Wednesday, July 12, 5:00PM-7:00PM, Room: Catalana, Chair: Brunella Gerla, Diego Valota Pietro Codara

5:00PM *On Semirings and MV Algebras* [#10]

Antonio Di Nola and Giacomo Lenzi, University of Salerno, Italy

We study commutative idempotent semirings in general, and some examples in particular. We show that the class Red of semiring reducts of MV-algebras, although axiomatized by a first order theory, is not axiomatized by a geometric theory (in the topos-theoretic sense) or a universal-existential first order theory. Then we perform comparisons between the class Red, the class of all semirings, and some so-called exotic semirings.

5:15PM *Non-preservation of Chosen Properties of Fuzzy Relational Compositions Based on Fuzzy Quantifiers* [#45]

Nhung Cao, Martin Stepnicka and Michal Holcapek, Institute for Research and Applications of Fuzzy Modeling (IRAFM), University of Ostrava, Czech Republic

Fuzzy relational compositions based on fuzzy quantifiers naturally do not preserve all the properties that are preserved for "standard" fuzzy relational compositions and, in many cases, the property is preserved only in a weaker form. For example, the associativity, that is preserved in the standard case derived from the universal and the existential quantifiers, generally does not hold for the case of compositions based on fuzzy quantifiers. However, is it the case that only the standard quantifiers lead to the preservation of such properties? Without any restriction on the shape of the fuzzy relations, the answer is positive.

5:30PM *Hahn-type Embedding Theorem for a Class of Residuated Chains* [#102]

Sandor Jenei, University of Pecs, Hungary

A structural description of absorbent-continuous group-like commutative residuated lattices over complete, order-dense chains will be presented. The theorem is sharp, no further generalization is possible. Group-like commutative residuated lattices will be characterized as Abelian lattice-ordered groups deprived of their cancellative property only. The so-called partial-lexicographic product constructions (two of them) will be introduced, which construct group-like commutative residuated lattices. As a side-effect, it gives rise to the so-called involutive ordinal sum construction, which constructs group-like commutative residuated lattices from a family of

6:15PM *An Adaptive Neuro-Fuzzy Inference System for the Qualitative Study of Perceptual Prominence in Linguistics* [#523]

Autilia Vitiello, Giovanni Acampora, Franco Cutugno, Petra Wagner and Antonio Origlia, University of Salerno, Italy; University of Naples Federico II, Italy; University of Bielefeld, Germany; University of Padova, Italy

This paper explores the applications of fuzzy logic inference systems as an instrument to perform linguistic analysis in the domain of prosodic prominence. Understanding how acoustic features interact to make a linguistic unit be perceived as more relevant than the surrounding ones is generally needed to study the cognitive processes needed for speech understanding. It also has technological applications in the field of speech recognition and synthesis. We present a first experiment to show how fuzzy inference systems, being characterised by their capability to provide detailed insight about the models obtained through supervised learning can help investigate the complex relationships among acoustic features linked to prominence perception.

group-like commutative residuated lattices. Via two decomposition theorems, corresponding to the partial-lexicographic product constructions, it will be shown that any order-dense group-like commutative residuated chain, which has only a finite number of idempotents can be built by iterating finitely many times the partial-lexicographic product constructions using solely totally ordered Abelian groups, as building blocks. The result extends the famous structural description of totally ordered Abelian groups by Hahn [4], to order-dense group-like commutative residuated chains with finitely many idempotents. group-like commutative residuated lattices. Via two decomposition theorems, corresponding to the partial-lexicographic product constructions, it will be shown that any order-dense group-like commutative residuated chain, which has only a finite number of idempotents can be built by iterating finitely many times the partial-lexicographic product constructions using solely totally ordered Abelian groups, as building blocks. The result extends the famous structural description of totally ordered Abelian groups by Hahn, to order-dense group-like commutative residuated chains with finitely many idempotents.

5:45PM *Extending Formal Concept Analysis using Intuitionistic \mathcal{L} -fuzzy Sets* [#281]

Ondrej Kridlo and Manuel Ojeda-Aciego, Institute of Computer Science, PF UPJS in Kosice, Slovakia; Departamento de Matematica Aplicada, Universidad de Malaga, Spain

A two-fold general approach to the theory of formal concept analysis is introduced by considering intuitionistic fuzzy sets valued on a residuated lattice as underlying structure for the construction.

6:00PM *Towards game semantics for nuanced logics* [#333]

Denisa Diaconescu and Ioana Leustean, University of Bucharest, Faculty of Mathematics and Computer Science, Romania

In this paper we study Moisil logic, a many-valued system based on the idea of nuancing. We prove a completeness theorem for graded deduction and make a first attempt towards a game semantics for this logic.

6:15PM *Standard completeness for extensions of IMTL* [#374]

Paolo Baldi, Agata Ciabattoni and Francesca Gulisano, Vienna University of Technology, Austria; Scuola Normale Superiore - Pisa, Italy

We provide a standard completeness proof which uniformly applies to a large class of axiomatic extensions of Involutive Monoidal T-norm Logic (IMTL). In particular, we identify sufficient conditions on the proof calculi which ensure density elimination and then standard completeness. Our argument contrasts with all previous approaches for involutive logics which are logic-specific.

6:30PM *On the relation between modal and multi-modal logics over Lukasiewicz logic* [#506]

Francesc Esteve, Lluís Godo and Ricardo Oscar Rodríguez, IIIA - CSIC, Spain; DC-FCEyN - UBA, Argentina

In a previous paper, it was shown that the (minimal) modal logic \mathcal{ML}_n with fuzzy accessibility relations over the finite-valued $\{L\}$ -Lukasiewicz logic \mathcal{L}_n and a corresponding multi-modal logic \mathcal{mML}_n (with a modality \Box_a for each value a in the n -valued \mathcal{L}_n -chain) had the same expressive

power when the language is extended with truth-constants. In this paper we partially extend these results partially when replacing the underlying logic \mathcal{L}_n by the infinite-valued $\{L\}$ -Lukasiewicz logic (with rational truth constants in the language). We prove that the (standard) tautologies of the modal logic \mathcal{ML} (resp. \mathcal{mML}) are in fact the common tautologies of all the logics \mathcal{ML}_n (resp. all the logics \mathcal{mML}_n) when letting n vary over \mathbb{N} . This fact opens the door to show an alternative proof of the finite model property for these logics and hence their decidability.

6:45PM *Involutive t-norms from non-simple MV-chains* [#561]

Stefano Aguzzoli, Anna Rita Ferraioli and Brunella Gerla, University of Milano, Italy; University of Insubria, Italy

We give a $[0,1]$ -functional representation of the finitely generated free algebras in the variety generated by Chang's MV-algebra C , and in the variety generated by the left continuous t-norm arising as Jenei's rotation J_{Π} of the product t-norm. We generalise the construction of J_{Π} from C by building a family T_n of involutive t-norm algebras such that the MV-algebras in the variety generated by T_n form the variety generated by S_n^{ω} and L_{n+1} .

Methods and Applications for Fuzzy Cognitive Maps

Wednesday, July 12, 5:00PM-7:00PM, Room: Giardino, Chair: Papageorgiou Elpiniki and Engin Yesil

5:00PM *Remarks on the Uncertainty Expansion Problem in Calculations of Models of Relational Fuzzy Cognitive Maps* [#227]

Grzegorz Slon and Alexander Yastrebov, Kielce University of Technology, Poland

During the modeling of uncertain and imprecise systems, the intelligent approach, based on the use of so-called Fuzzy Cognitive Maps (FCM) is often used. Constructors of the FCM models usually use a technique, in which fuzzy quantities are converted to their crisp equivalents (e.g. in a model learning phase). Such a procedure converts the fuzzy model in a crisp model, which may be a problem in systems with uncertainty. This risk can be avoided by building a model based on fuzzy numbers, fuzzy relations and fuzzy arithmetic operations, but then the new problem - of technical nature - arises, related to the specifics of operations on fuzzy numbers - manifested in the support deformations. The paper proposes a solution to this problem, consisting in a new look at the interpretation of the results of arithmetic operations on fuzzy numbers. New mechanism, that allows overcoming the negative effects of such deformations, is presented. The use of the proposed approach enables maintaining the fuzzy nature of the model at each stage of its operation. The results of simulations for different variants of the proposed method are also shown.

5:15PM *Medical Decision Making Based on Fuzzy Cognitive Map and a Generalization Linguistic Weighted Power Mean for Computing with Words* [#240]

Azam Najafi, Abdollah Amirkhani, Elpiniki I. Papageorgiou and Mohammad R. Mosavi, Iran University of Science and Technology, Iran; Technological Educational Institute of Central Greece, Greece

Given high uncertainty in medicine, it is essential to use some approaches to deal with this uncertainty. Therefore, this article utilizes computing with words (CWW) in fuzzy cognitive maps (FCMs) for the application of a new medical decision support system. In this framework, expressed as CWW FCM, all concepts and the weights of connecting links between them are described based on interval type-2 membership functions (IT2 MFs) expressed as a set of words. This type of FCM structure shows high performance by taking into account uncertainties in experts' opinions and in system parameters in the

process of modeling. In this paper, we utilize CWW FCM to classify celiac disease (CD), a chronic disorder. Thus, to illustrate the behavior and performance of the proposed model in classifying CD, we have collected a real dataset from patients with different types of CD. Applying the model on this dataset, acceptable accuracy in classification is achieved.

5:30PM *A new approach using Mixed Graphical Model for automatic design of Fuzzy Cognitive Maps from ordinal data* [#345]

Zoumpolia Dikopoulou, Elpiniki Papageorgiou, Vijay Mago and Koen Vanhoof, Hasselt University, Belgium; Technological Educational Institute of Sterea Ellada, Greece; Lakehead University, Canada

This research study proposes a new method for automatic design of Fuzzy Cognitive Maps (FCM) using ordinal data based on the efficient capabilities of mixed graphical models. The approach is able to model all variables on the proper domain of ordinal data by combining a new class of Mixed Graphical Models (MGMs) with a structure estimation approach based on generalized covariance matrices. It can work with a large amount of categorical data. It represents its structure as a sparser graph, while maintaining a high likelihood, by producing an adjacent weight matrix, where relationships are expressed by conditional independences. By maximizing the likelihood indicates that the model fits better to the data under the assumption that the observed data are the most likely data. The whole approach was implemented in a business intelligence problem of evaluating the attractiveness of Belgian companies. Through the analysis of results and conducted scenarios, the usefulness of the proposed MGM method for designing FCM capable to make decisions, is demonstrated. Comparisons with the previous known methodology for automatic construction of FCMs based on distance-based algorithm, showed that the proposed approach provides more understandable/useful relationships among nodes, through a less complex structure for making decisions.

5:45PM *Striving for Semantic Convergence with Fuzzy Cognitive Maps and Graph Databases* [#440]

Sara D'Onofrio, Marcel Wehrle, Edy Portmann and Thomas Myrach, University of Bern, Switzerland; University of Fribourg, Switzerland

The exponentially rising amounts of urban data demand new conceptual and technical methods for their management and storage. The era of the

Semantic Web requires a convergence toward commonly shared meanings. The combination of fuzzy cognitive maps with graph databases is a first approach to a solution. This article determines the basic requirements for the storing of fuzzy cognitive maps to test current graph databases for their structural suitability. Six out of 47 graph databases fulfill the requirements and are thus recommended for further research purposes. As a proof of concept, OrientDB is used to present how a semantic convergence can be reached through the combination of fuzzy cognitive maps and graph databases in a cognitive city by tackling fuzziness.

6:00PM *Interval Valued Data Enhanced Fuzzy Cognitive Maps: Towards an Approach for Autism Deduction in Toddlers* [#503]

Alya Al-Farsi, Faiyaz Doctor, Dobrila Petrovic, Sudhagar Chandran and Charalampos Karyotis, Middle East Collage, Oman; Coventry University, United Kingdom

Fuzzy Cognitive Maps (FCMs) are a soft computing technique characterized by robust properties that make them an effective technique for medical decision support systems. Making decisions within a medical domain is difficult due to the existence of high levels of uncertainty. The sources of this uncertainty can be due to the variation of physicians' opinions and experiences. The structure of existing FCMs is based on type -1 fuzzy sets in order to represent the causal relations among concepts of the modeled system. Therefore, the ability of the FCM to handle high levels of

uncertainties and deliver accurate results can be hindered. In this paper, we propose using the Interval Agreement Approach to model the weights of links in FCMs to capture high level uncertainties in the presence of imprecise data acquired from different medical experts to enhance its decision modelling and reasoning capability. The proposed model is used in identifying if a child is diagnosed with an Autism Spectrum Disorder (ASD) where the Modified Checklist for Autism in Toddlers is used as a standard tool to derive the inputs for the FCMs. Initial results demonstrate that the proposed method outperforms conventional FCMs in classifying ASD based on a dataset of diagnosed cases.

6:15PM *Improving the Performance of Classification Models with Fuzzy Cognitive Maps* [#71]

Panayiotis Christodoulou, Andreas Christoforou and Andreas S. Andreou, Cyprus University of Technology, Cyprus

This paper presents a novel approach to improve the accuracy of classification models used for prediction purposes by integrating a Fuzzy Cognitive Map (FCM) to produce a hybrid model. The proposed methodology first uses the FCM to discover latent correlations that exist between the data in order to form a single variable. This variable is then fed in the classification model as part of the training and testing phases to enhance its accuracy. Experimental results using datasets describing two different problems suggested noteworthy improvements in the accuracy of various classification models.

Interpretable Fuzzy Systems

Wednesday, July 12, 5:00PM-7:00PM, Room: Borbonica, Chair: Corrado Mencar, José M. Alonso, Castiello

5:00PM *The FISDeT Software: Application to Beer Style Classification* [#184]

Giovanna Castellano, Ciro Castiello and Anna Maria Fanelli, University of Bari Aldo Moro, Italy

This paper presents FISDeT, a Python tool that enables the design of a Fuzzy Inference System (FIS) based on the standard language FCL. FISDeT includes a GUI that enables the user to easily define and update the rule base of a FIS. Given a FIS, the tool can perform the inference of fuzzy rules. To show the main features of FISDeT, in this paper we employ the tool to develop fuzzy rule-based systems that can solve the problem of beer style classification. The integrated testing facilities of FISDeT enable a comparison among the created classifiers.

5:15PM *An Exploratory Study on the Benefits of using Natural Language for Explaining Fuzzy Rule-based Systems* [#166]

Jose M. Alonso, Alejandro Ramos-Soto, Ehud Reiter and Kees van Deemter, Universidade de Santiago de Compostela, Spain; University of Aberdeen, Scotland

This paper presents an empirical research. It focuses on testing empirically the benefits of providing users, in a specific domain, with textual interpretation of the fuzzy inferences carried out by a fuzzy classifier for a given selection of samples. The hypothesis to test is as follows: "Users understand easier the decision made by a fuzzy system when they are provided with a textual interpretation of the fuzzy inference mechanism that the system carried out". This hypothesis was successfully tested in a web survey. The application domain was leaf classification. The fuzzy classifiers were built with the GUAJE fuzzy modeling open source software which is aimed at generating interpretable fuzzy systems. The textual interpretation was handmade by an expert who followed the guidelines of the Natural Language Generation approach proposed by

Reiter and Dale. Reported results encourage us to go on with a series of additional experiments devoted to deeply explore how Natural Language Generation techniques can contribute to facilitate the understanding of fuzzy systems.

5:30PM *Looking for a real-world-semantics-based approach to the interpretability of fuzzy systems* [#267]

Cat Ho Nguyen and Jose M. Alonso, Institute of Information Technology, Viet Nam Academy of Science and Technology, Viet Nam; Universidade de Santiago de Compostela, Spain

The existing studies of the interpretability of fuzzy systems have mainly focused on the analysis of the relation between a model of the fuzzy system and a human user considered as a beneficiary, i.e., a domain expert or a designer. Suggested by the concepts of "model" of formalized theories, "realization" of formalized language, and "interpretability" of a theory in another, the main contribution of this paper is the proposal of a new approach to the fuzzy system interpretability. This is grounded on the qualitative real-world semantics of words and relationships between the semantics of fuzzy system components and substructures of their real-world counterparts. Thus, we introduce a novel real-world-semantics-based approach. It is aimed at characterizing the so-called real-world-semantics-based interpretability of fuzzy systems. In addition, it considers the actual semantics of all fuzzy system components, including the inference engine. Moreover, this new approach opens the door to a new way to study the interpretability of fuzzy systems.

5:45PM *Efficiency Improvement of DC* through a Genetic Guidance* [#299]

Ciro Castiello, Corrado Mencar, Marco Lucarelli and Franz Rothlauf, University of Bari "A. Moro", Italy; SITAE S.p.A., Italy; University of Mainz "J. Gutenberg", Germany

DC* is a method for generating interpretable fuzzy information granules from pre-classified data. It is based on the subsequent application of LVQ1 for data compression and an ad-hoc procedure based on A* to represent data with the minimum number of fuzzy information granules satisfying some interpretability constraints. While being efficient in tackling several problems, the A* procedure included in DC* may happen to require a long computation time because the A* algorithm has exponential time complexity in the worst case. In this paper, we approach the problem of driving the search process of A* by suggesting a close-to-optimal solution that is produced through a Genetic Algorithm (GA). Experimental evaluations show that, by driving the A* algorithm embodied in DC* with a GA solution, the time required to perform data granulation can be reduced by at least 45% and up to 99%.

6:00PM *Interpretability Indices for Hierarchical Fuzzy Systems* [#361]

Tajul Rosli Razak, Jonathan Garibaldi, Christian Wagner, Amir Pourabdollah and Daniele Soria, Intelligent Modelling and Analysis Group, Lab for Uncertainty in Data and Decision Making (LUCID), School of Computer Science, The University of Nottingham, United Kingdom; Department of Computer Science, University of Westminster, United Kingdom

Hierarchical fuzzy systems (HFSs) have been shown to have the potential to improve interpretability of fuzzy logic systems (FLSs). In recent years, a variety of indices have been proposed to measure the interpretability of FLSs such as the Nauck index and Fuzzy index. However, interpretability

indices associated with HFSs have not so far been discussed. The structure of HFSs, with multiple layers, subsystems, and varied topologies, is the main challenge in constructing interpretability indices for HFSs. Thus, the comparison of interpretability between FLSs and HFSs—even at the index level—is still subject to open discussion. This paper begins to address these challenges by introducing extensions to the FLS Nauck and Fuzzy interpretability indices for HFSs. Using the proposed indices, we explore the concept of interpretability in relation to the different structures in FLSs and HFSs. Initial experiments on benchmark datasets show that based on the proposed indices, HFSs with equivalent function to FLSs produce higher indices, i.e. are more interpretable than their corresponding FLSs.

6:15PM *A first approach to a fuzzy classification system for age estimation based on the pubic bone* [#600]

Pedro Villar, Inmaculada Aleman, Laura Castillo, Sergio Damas and Oscar Cordon, University of Granada, Spain

The study of human remains suffers from a lack of information for determining a reliable estimation of the age of an individual. One of the most extended methods for this task was proposed in the twenties of the past century and is based on the analysis of the pubic bone. The method describes some age changes occurring in the pubic bone and establishes ten different age ranges with a description of the morphological aspect of the bone in each one of them. These descriptions are sometimes vague and there is not a systematic way for using the method. In this contribution we propose two different preliminary fuzzy rule-based classification system designs for age estimation from the pubic bone that consider the main morphological characteristics of the bone as independent and linguistic variables. So, we have identified the problem variables and we have defined the corresponding linguistic labels making use of forensic expert knowledge, that is also considered to design a decision support fuzzy system. A brief collection of pubic bones labeled by forensic anthropologists has been used for learning the second fuzzy rule-based classification system by means of a fuzzy decision tree. The experiments developed report a best performance of the latter approach.

Fuzzy Data Science II

Wednesday, July 12, 5:00PM-7:00PM, Room: Auditorium, Chair: Yusuke Nojima Sushmita Mitra

5:00PM *The Kolmogorov Goodness-of-Fit Test for Interval-Valued Data* [#261]

Przemyslaw Grzegorzewski, Systems Research Institute, Polish Academy of Sciences, Poland

The generalized Kolmogorov goodness-of-fit test for interval-valued data is proposed. Two versions of the test are considered – each corresponding to a different view on the outcomes of the experiment, i.e. either the epistemic or ontic one. It is shown that each view on interval-valued data yield different approaches to data analysis and statistical inference.

5:15PM *Unsupervised Classification of Smartphone Activities Signals Using Wavelet Packet Transform and Half-Cosine Fuzzy Clustering* [#274]

Hong He, Yonghong Tan and Jifeng Huang, Shanghai Normal University, China

Activity recognition using smartphone provides a ubiquitous and unobtrusive way for people to realize health monitor and ambient assisted living. Since human activities has characteristics of high complexity and diversity, the accurate identification of activity greatly depends on the appropriate features extracted from limited smartphone signals and the efficiency of pattern recognition approaches. An unsupervised classification scheme based on the wavelet packet transform (WPT) and the half-cosine fuzzy clustering (HFC) is

proposed in this paper for the automatic feature extraction and recognition of human activities on smartphone. The wavelet packet coefficient features combined with statistic features describe the sensor signals comprehensively. The novel half-cosine initialization eliminates the sensitivity of the fuzzy clustering to initial center distribution. Experiment results of public datasets reveal that the WP-based hybrid features are more suitable for human activity recognition than statistic features. The performance of proposed half-cosine fuzzy clustering is superior than those of FCM, HAC and K-means for the activity recognition on smartphone.

5:30PM *Heterogeneous Unsupervised Domain Adaptation Based on Fuzzy Feature Fusion* [#278]

Feng Liu, Guangquan Zhang and Jie Lu, University of Technology Sydney, Australia

Domain adaptation is a transfer learning approach that has been widely studied in the last decade. However, existing works still have two limitations: 1) the feature spaces of the domains are homogeneous, and 2) the target domain has at least a few labeled instances. Both limitations significantly restrict the domain adaptation approach when knowledge is transferred across domains, especially in the current era of big data. To address both issues, this paper proposes a novel fuzzy-based heterogeneous unsupervised domain adaptation approach. This approach maps the feature spaces of the source and target domains onto the same latent space

constructed by fuzzy features. In the new feature space, the label spaces of two domains are maintained to reduce the probability of negative transfer occurring. The proposed approach delivers superior performance over current benchmarks, and the heterogeneous unsupervised domain adaptation (HeUDA) method provides a promising means of giving a learning system the associative ability to judge unknown things using related knowledge.

5:45PM *A New Dynamic Approach for Non-Singleton Fuzzification in Noisy Time-Series Prediction* [#288]

Amir Pourabdollah, Robert John and Jonathan Garibaldi, The University of Nottingham, United Kingdom

Non-singleton fuzzification is used to model uncertain (e.g. noisy) inputs within fuzzy logic systems. In the standard approach, assuming the fuzzification type is known, the observed [noisy] input is usually considered to be the core of the input fuzzy set, usually being the centre of its membership function. This paper proposes a new fuzzification method (not type), in which the core of an input fuzzy set is not necessarily located at the observed input, rather it is dynamically adjusted based on statistical methods. Using the weighted moving average, a few past samples are aggregated to roughly estimate where the input fuzzy set should be located. While the added complexity is not huge, applying this method to the well-known Mackey-Glass and Lorenz time-series prediction problems, show significant error reduction when the input is corrupted by different noise levels.

6:00PM *Fuzzy Quantified Queries to Fuzzy RDF Databases* [#388]

Olivier Pivert, Olfa Slama and Virginie Thion, Rennes 1 University, France

In a relational database context, fuzzy quantified queries have been long recognized for their ability to express different types of imprecise and flexible information needs. In this paper, we introduce the notion of fuzzy quantified statements in a (fuzzy) RDF database context. We show how these statements can be defined and implemented in FURQL, which is a fuzzy extension of the SPARQL query language that we previously proposed. Then, we present some experimental results that show the feasibility of this approach.

6:15PM *Possibilistic-based type1 beta fuzzy for numerical information fusion* [#462]

Hanan Raissi, Hanene Guesmi and Adel M. Alimi, REGIM-Lab Sfax, Tunisia

In this paper, we propose to present a novel numerical information fusion method at the feature level. This method is based on the possibility theory using the Beta function and the type1 fuzzy theory. In this method, we proceed to estimate the possibility distribution of the numerical features by using the Beta function. So, we constitute the Beta-possibilistic knowledge base. Then, this Beta-possibilistic knowledge base will be the input of the fuzzy numerical features fusion method. We have evaluated this numerical information method on 15 benchmark databases. Also, we have compared this method with our numerical information fusion method based on the Beta-possibilistic reasoning and with four another numerical information fusion methods in order to determine the best one.