IEEE 2020 TUTORIAL PROPOSAL

Tutorial title: Foundations of Fuzzy Networks

Tutorial organisers:

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Alexander Gegov is Reader in Computational Intelligence in the School of Computing, University of Portsmouth, UK. He holds a PhD in Control Systems and a DSc in Intelligent Systems – both from the Bulgarian Academy of Sciences. He has been a recipient of a National Annual Award for Best Young Researcher from the Bulgarian Union of Scientists. He has been Humboldt Guest Researcher at the University of Duisburg in Germany. He has also been EU Visiting Researcher at the University of Wuppertal in Germany and the Delft University of Technology in the Netherlands.

Alexander Gegov's research interests are in the development of computational intelligence methods and their application for modelling and simulation of complex systems and networks. He has edited 6 books, authored 5 research monographs and over 30 book chapters – most of these published by Springer. He has authored over 50 articles and 100 papers in international journals and conferences – many of these published and organised by IEEE. He has also presented over 20 invited lectures and tutorials – most of these at IEEE Conferences on Fuzzy Systems, Intelligent Systems, Computational Intelligence and Cybernetics.

Alexander Gegov is Associate Editor for 'IEEE Transactions on Fuzzy Systems', 'Fuzzy Sets and Systems', 'Intelligent and Fuzzy Systems' and 'Computational Intelligence Systems'. He is also Reviewer for several IEEE journals and Assessor for several National Research Councils. He is Member of the IEEE Computational Intelligence Society and the Soft Computing Technical Committee of the IEEE Society of Systems, Man and Cybernetics. He is also Guest Editor for the forthcoming Special Issue on Deep Fuzzy Models of the IEEE Transactions on Fuzzy Systems.

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Farzad Arabikhan joined the University of Portsmouth as a lecturer in 2017. He completed his PhD on 2017 at the University of Portsmouth and his thesis focus was on Modelling Telecommuting using Fuzzy Networks. In his research, he optimised Fuzzy Networks using

Genetic Algorithms and data mining approaches. Having published his research results in several journal and conference papers, he has also secured funding from European Cooperation in Science and Technology (COST) to collaborate with European scholars in University Paris 1 Pantheon Sorbonne, Paris, France and Mediterranean University of Reggio Calabria to pursue his research activities. He holds BSc and MSc degrees in Civil and Transportation Engineering from the Sharif University of Technology, Tehran, Iran.

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David Sanders is Professor of Systems Engineering in the School of Mechanical and Design Engineering, University of Portsmouth, UK. He has been doing research in the area of powered wheelchairs and mobile robots for thirty-five years with many established collaborators at a national and international level. He began academic research with a Eureka PROMETHEUS Project in the early nineties on a large driverless cars project. He has received a top grade 5 Alpha Excellent grading for his EPSRC grant on the design and analogue control of powered wheelchairs. He has been Principal Investigator for several projects concerning control and sensors. He was awarded a Leverhulme Trust Senior Research Fellowship in 2014 to trial some of the new powered wheelchair ideas with pilot projects.

David Sanders has extensive experience in driverless vehicles and assistive technology research, mostly funded by industry, NATO, RCUK, EU and the British Council. His research has already resulted in new collision avoidance, control and effort-reduction systems for powered wheelchairs. That research has been based on many years of work into climbing, walking and mobile robots.

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Boriana Vatchova is Associate Professor in Informatics and Computer Sciences at the Institute of Information and Communication Technologies at the Bulgarian Academy of Sciences, Sofia, Bulgaria. She holds PhD in Intelligent Systems from the Bulgarian Academy of Sciences and MSc in Electronics and Automatics from the Technical University, Sofia, Bulgaria. She has been DAAD Visiting Researcher at the Institute of Control Theory at the Technical University, Dresden, Germany and Visiting Erasmus Lecturer at the School of Computing, University of Portsmouth, UK.

Boriana Vatchova's research interests are in the field of modeling of complex systems using probabilistic methods, multi-valued and fuzzy logic. She has authored a research monograph,

3 book chapters and 30 articles some of which have been published by IEEE. She is Member of the Union of Automatics and Informatics and the European Complex System Society. She has been a part-time lecturer in Software Engineering and Informatics at the University of Telecommunications and Post, Sofia, Bulgaria.

Tutorial goal:

The tutorial highlights the advantages of fuzzy networks for building more transparent models of complex systems consisting of interacting subsystems. It also shows the complementary nature of fuzzy networks with regard to standard and hierarchical fuzzy systems.

Tutorial plan:

The proposed format for the tutorial is based on two parts. The first part will focus on theoretical foundations of fuzzy networks within the first half an hour. The second part will focus on practical applications of fuzzy networks within the second half an hour.

Tutorial outline:

The tutorial focuses on the theoretical foundations of fuzzy networks. The nodes of these networks are fuzzy systems represented by rule bases and the connections between the nodes are outputs from and inputs to these rule bases.

Fuzzy networks have an underlying two-dimensional grid structure with horizontal levels and vertical layers. The levels represent spatial hierarchy in terms of network breadth and the layers represent temporal hierarchy in terms of network depth.

The nodes of fuzzy networks are modelled by Boolean matrices or binary relations. The connections between the nodes are modelled by block schemes or topological expressions. Each network node is located in a cell within the underlying grid structure.

Nodes in fuzzy networks are manipulated by merging and splitting operations. The merging operations are for network analysis and the splitting operations are for network design. These operations are used for converting a fuzzy network into a fuzzy system and vice versa.

The operations are illustrated on feedforward and feedback fuzzy networks. Feedforward networks include combinations of narrow/broad and shallow/deep network structures. Feedback networks include combinations of single/multiple and local/global feedback loops.

Fuzzy networks are applied to case studies from engineering, computing, transport and finance. They are validated successfully against standard and hierarchical fuzzy systems. The validation uses performance evaluation indicators for feasibility, accuracy, efficiency, transparency.

Tutorial justification:

The potential audience for the tutorial includes mainly PhD students, researchers and academics. The proposed duration of one hour is appropriate for introducing the material to the audience. The organisers are well qualified based on their expertise in the topic.

Tutorial references:

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[3] A.Gegov, F.Arabikhan and N.Petrov, Linguistic composition based modelling by fuzzy networks with modular rule bases, *Fuzzy Sets and Systems* 269 (2015) 1-29
[4] X.Wang, A.Gegov, F.Arabikhan, Y.Chen and Q.Hu, Fuzzy network based framework for software maintainability prediction, *Uncertainty, Fuzziness and Knowledge Based Systems* 27/5 (2019) 841-862
[5] A.Yaakob, A.Serguieva and A.Gegov, FN-TOPSIS: Fuzzy networks for ranking traded equities, *IEEE Transactions on Fuzzy Systems* 25/2 (2016) 315-332
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[7] A.Gegov, N.Petrov and E.Gegov, Rule base identification in fuzzy networks by Boolean matrix equations, *Intelligent and Fuzzy Systems* 26/1 (2014) 405-419
[8] A.Gegov, N.Petrov, D.Sanders and B.Vatchova, Boolean matrix equations for node identification in fuzzy rule based networks, *Knowledge Based and Intelligent Engineering Systems* 21/2 (2017) 69-83
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[10] A.Gegov, N.Petrov, B.Vatchova and D.Sanders, Advanced Modelling of Complex Processes by Fuzzy Networks, *WSEAS Transactions on Circuits and Systems* 10/10 (2011) 319-330