Learning Fuzzy Systems from Data: A Modern Approach

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Extended Abstract: The past three decades have witnessed the substantial growth of fuzzy systems in general and learning fuzzy systems from data in particular. Different from other paradigms in computational intelligence and machine learning, the distinguished feature of the fuzzy system paradigm is that it utilizes the dual system representations: a linguistic rule base for the interpretable and transparent knowledge representation and a nonlinear mathematical model for enabling the accurate representation and learning from data. From this point of view, the talk focuses on the modern approach to the learning fuzzy systems from data, including our research results in this topic.

The first part of this talk introduces the problem of learning fuzzy systems from data, and then gives a briefly historical review of the progress and evolution of learning fuzzy systems from data.

The second part of this talk presents the theoretical foundations of learning fuzzy systems from data including

- Introduce different types of fuzzy systems such as Mamdani fuzzy systems, Takagi-Sugeno fuzzy systems, fuzzy neural networks and hierarchical fuzzy systems, in particular, the similarities and differences between these fuzzy system models will be analyzed.
- Analyze the representation power and university approximation properties of fuzzy systems, and show the generality and wide applicability of fuzzy systems.
- Discuss the interpretability and transparency of fuzzy systems and the conditions for their realization.

The third part of this talk focuses on the different frameworks and paradigms for learning fuzzy systems from data. This part starts introducing the different aspects of learning problems including the structure and parameter learning, offline and online learning; then the different frameworks and approach of learning fuzzy systems from data are presented and discussed in details:

- Traditional expert-based approach of building fuzzy rule based systems
- Partition-based approach of constructing fuzzy systems
- Tree search-based approach for identifying fuzzy systems
- Clustering based approach for learning fuzzy system
- Genetic fuzzy system approach (that is, learning fuzzy systems by genetic or evolutionary algorithms)
- Evolving fuzzy systems and self-organizing fuzzy neural network (that is, online learning fuzzy systems and fuzzy neural networks) from stream data and under non-stationary environment.
- Gradient based approach for learning hierarchical fuzzy systems
- Multi-level learning approach of fuzzy neural networks
- Block structured sparse representation approach
- Similarity based structure simplification approach
- Hybrid approach of learning fuzzy systems

At the end of this part, different approaches are compared, their applicability is discussed, and their advantages and disadvantages are identified.

The fourth part of this talk present some applications to show the usefulness of different learning approaches of fuzzy systems from data and to illustrate various issues when apply fuzzy system approach in applications. These application examples are mainly based on our research and include

- Retail site performance modeling and selection decision support
- Energy power load forecasting
- Learning based negotiation pricing and decision support
- Stock market movement forecasting
- Control system modelling and identification

The last part of this talk presents remaining challenges and future research topics including

- Theoretic accuracy analysis based on the noise level of data to support the model selection
- Trade-off model complexity and accuracy
- Multi-granular fuzzy systems for interpretability and high accuracy
- Learning fuzzy systems to support decision making and its special requirements
- Hierarchical and deep structure learning of fuzzy systems
- Learning fuzzy systems from data with time varying and dynamic structure systems
- Online feature selection and learning varying dimensional fuzzy systems
- Real-time learning for high speed big data streams
- Learning fuzzy systems from super-high or infinite dimensional big data

The main aim of this talk is not to provide a comprehensive review of learning fuzzy systems from data, but to present the key issues and insights in the state of art and illustrate the opportunities for further research and development in non-stationary, time varying, complicated, and big data.

Brief Biography:

Dr Xiao-Jun Zeng received his Ph.D. degree in Computation from the University of Manchester, where he is currently a Senior Lecturer in Machine Learning and Optimisation at the School of Computer Science. Before joining the University of Manchester in 2002, he was with Knowledge Support Systems, Ltd., Manchester, between 1996-2002, where he was the Head of Research, developing intelligent pricing decision support systems which won the European Information Society Technologies Award in 1999 and Microsoft European Retail Application Developer (RAD) Awards in 2001 and 2003. His research in intelligent pricing decision support systems was selected by UKCRC, CPHC, and BCS Academy as one of 20 impact cases to highlight the impact made by UK academic Computer Science Research within the UK and worldwide over the period 2008 – 2013. .

Dr Zeng's main research interests include fuzzy systems, computational intelligence, machine learning, big data and data mining, decision support systems, computational finance and game theory, and their applications. He has published more 100 journal and conference papers in these areas and his research has been funded UK EPSRC, Innovate UK TSB, EU 6th and 7^{th} Framework Programmes, and EU H2020 Programme. His currently funded projects include "hierarchical and real-time big data analytics for performance analysis and prediction of mobile networks" by EPSRC Impact Acceleration Account with Wadaro Ltd and "Big Data in Finance" by EU Horizon 2020 Framework Programme.

Dr Zeng has served to scholarly and professional communities in various roles including an Associate Editor of the IEEE Transactions on Fuzzy Systems, Special Session Chair of 2008 IEEE World Congress on Computational Intelligence, Program Chair of 2009- 2016 IEEE Symposium on Computational Intelligence in Control and Automation, Program Co-Chair of the 9th Int Conference on Fuzzy Systems and Knowledge Discovery, and the General Chair of 11th annual UK Workshop on Computational Intelligence, as well as an elected member of the UK EPSRC College. He is also a member of Fuzzy Systems Technical Committee and Intelligent Systems Applications Technical Committee of IEEE Computational Intelligence Society.