Guest Editorial for the Special Section on Brain Computer Interface (BCI)

A BRAIN computer interface (BCI) enables direct communication between the brain and a computer. It can be used to research, repair, or enhance human cognitive or sensory-motor functions. BCIs have attracted rapidly increasing research interest in the last decade, thanks to recent advances in neurosciences, wearable/mobile biosensors, and analytics. However, there are many challenges in the transition from laboratory settings to real-life applications, including the reliability and convenience of the sensing hardware, the availability of high-performance and robust algorithms for signal analysis and interpretation, and fundamental advances in automated reasoning that enable the reasoning and generalization across individuals.

Computational intelligence techniques, particularly fuzzy sets and systems, have demonstrated outstanding performance in handling uncertainties in many real-world applications. They have also started attracting more attentions in the BCI domain. More specifically, fuzzy sets and systems have been used in electroencephalogram (EEG) feature extraction (e.g., self-organizing fuzzy neural networks, fuzzy region of interest, and fuzzy wavelet packet), pattern recognition [e.g., fuzzy adaptive resonance theory mapping (ARTMAP), type-1 and type-2 fuzzy logic systems, fuzzy-neural systems, fuzzy *c*-means clustering, fuzzy integrals, fuzzy support vector machine, fuzzy similarity, and rough sets], optimization (e.g., fuzzy particle swarm optimization), etc.

The five articles in this special section of the IEEE TRANSACTIONS ON FUZZY SYSTEMS represent some of the latest progress on the combination of fuzzy logic and BCI. They were selected from 37 submissions through peer-review and provide a highly interesting view of the current research and potential avenues of fuzzy sets and systems in BCI. The breadth of the research captured by these articles provides an indication of the importance of BCI in human-machine interaction and indicates the potential for further development of fuzzy logic in this space.

The paper entitled "Brain Machine Interface and Visual Compressive Sensing based Teleoperation Control of an Exokeleton Robot," by Qiu *et al.*, presents a brain-machine interface and vision feedback based fuzzy teleoperation control approach for an exoskeleton robot. Real-time visual-feedback allows the user to visualize the manipulator's workspace and the movements being executed. Compressed images are used as feedback errors to elicit steady-state visual evoked potentials (SSVEP) EEG signals. A local adaptive fuzzy controller is designed to drive the exoskeleton tracking the intended trajectories in the user's mind.

The paper entitled "Psycho-Physiologically-Based Real Time Adaptive General Type 2 Fuzzy Modelling and Self-Organising Control of Operator's Performance Undertaking a Cognitive Task," by Torres-Salomao *et al.*, presents a fuzzy logic based modeling and control framework to prevent performance breakdown in human-computer interactive systems. The adaptive, self-organizing and interpretable modeling framework based on general type-2 fuzzy sets is able to learn in real-time without prior training. The resulting model is later used in an energy model based controller, which infers appropriate control actions by changing the difficulty level of the arithmetic operations in human computer interaction.

The paper entitled "Designing an Interval Type-2 Fuzzy Logic System for Handling Uncertainty Effects in Brain-Computer Interface Classification of Motor Imagery Induced EEG Patterns," by Herman *et al.*, examines the applicability of interval type-2 fuzzy logic system to handling uncertainties associated with the complexity and variability of brain dynamics, reflected by nonstationary EEG signals. It presents an interval type-2 fuzzy logic classifier that can robustly deal with within-session and intersession manifestations of nonstationary spectral EEG correlates of motor imagery (MI), and a comprehensive examination of the proposed approach in both offline and online EEG classification.

The paper entitled "Fuzzy Integral with Particle Swarm Optimization for a Motor-Imagery-based Brain-Computer Interface," by Wu *et al.*, also studies the MI paradigm in BCI. It proposes an ensemble approach to cope with the individual differences in MI-related rhythmic patterns. The diverse base classifiers are constructed using a sub-band common spatial pattern method, and aggregated by a fuzzy integral, which is in turn optimized by particle swarm optimization. The proposed approach exhibits robust performance in offline single-trial classification of MI and real-time control of a robotic arm using MI.

The paper entitled "Recognition of Epileptic EEG Signals Using a Novel Multi-View TSK Fuzzy System," by Jiang *et al.*, proposes an epileptic EEG recognition approach based on multi-view learning and the TSK fuzzy system. First, multiview EEG data are generated by employing different feature extraction methods. Then, they are used in a TSK fuzzy model to identify epileptic EEG signals. Experimental results indicate that the proposed approach is promising when compared with several state-of-the-art algorithms.

In summary, the five selected papers for this special section highlight a subset of the challenging and novel applications of fuzzy systems and systems to BCI. We would like to express our sincere thanks to all the authors and gratitude to the reviewers for extending their cooperation in preparing and revising the papers.

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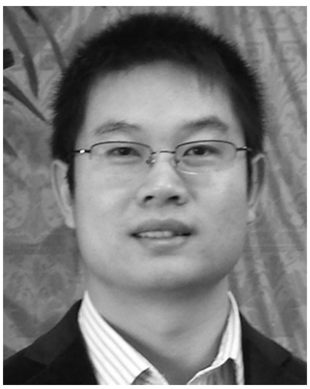
DONGRUI WU, *Co-Guest Editor*
DataNova
Clifton Park, NY 12065-6832 USA

BRENT J. LANCE, *Co-Guest Editor*
Human Research and Engineering Directorate
Army Research Laboratory
Adelphi, MD 20783 USA

VERNON J. LAWHERN, *Co-Guest Editor*
Human Research and Engineering Directorate
Army Research Laboratory
Adelphi, MD 20783 USA



Dongrui Wu (S'05–M'09–SM'14) received the B.E. degree in automatic control from the University of Science and Technology of China, Hefei, China, in 2003, the M.Eng. degree in electrical engineering from the National University of Singapore, Singapore, in 2005, and the Ph.D. degree in electrical engineering from the University of Southern California, Los Angeles, CA, USA, in 2009.

He was a Lead Research Engineer at GE Global Research from 2010 to 2015. He is currently a Chief Scientist with DataNova, Clifton Park, NY, USA. His research interests include affective computing, brain–computer interface, computational intelligence, and machine learning. He has more than 90 publications, including a book entitled *Perceptual Computing* (Wiley-IEEE, 2010).

Dr. Wu received the IEEE International Conference on Fuzzy Systems Best Student Paper Award in 2005, the IEEE Computational Intelligence Society Outstanding Ph.D. Dissertation Award in 2012, the IEEE TRANSACTIONS ON FUZZY SYSTEMS Outstanding Paper Award in 2014, and the North American Fuzzy Information Processing Society Early Career Award in 2014. He was a finalist of the IEEE TRANSACTIONS ON AFFECTIVE COMPUTING's Most Influential Paper Award in 2015, and the IEEE Brain Initiative Best Paper Award in 2016. He was a selected participant of the first Heidelberg (Abel/Fields/Turing) Laureate Forum in 2013, the National Academy of Engineering German–American Frontiers of Engineering Symposium in 2015, and the 13th Annual National Academies Keck Futures Initiative Conference in 2015. He is an Associate Editor of the IEEE TRANSACTIONS ON FUZZY SYSTEMS, the IEEE TRANSACTIONS ON HUMAN-MACHINE SYSTEMS, and the *IEEE Computational Intelligence Magazine*.

Brent J. Lance (SM'14) received the Ph.D. degree in computer science from the University of Southern California (USC), Los Angeles, CA, USA, in 2008.

He then worked at the Institute for Creative Technologies (ICT), USC, as a Postdoctoral Researcher before joining the Human Research and Engineering Directorate (HRED), Army Research Laboratory (ARL) in 2010, Adelphi, MD, USA, where he is currently a Research Scientist. At HRED, he works on improving robustness of EEG-based Brain-Computer Interaction through improved integration with autonomous systems. He has published more than 35 technical articles, including a first-author publication on Brain-Computer Interaction in the 100th anniversary edition of the PROCEEDINGS OF THE IEEE.

Dr. Lance is a Member of the Association for Computing Machines. He is an Associate Editor of the IEEE TRANSACTIONS ON NEURAL SYSTEMS AND REHABILITATION ENGINEERING.

Vernon J. Lawhern (M'16) received the B.S. degree in applied mathematics from the University of West Florida, Pensacola, FL, USA, in 2005, and the M.S. and Ph.D. degree in statistics from the Florida State University, Tallahassee, FL, USA, in 2008 and 2011, respectively.

He is currently a Mathematical Statistician in the Human Research and Engineering Directorate, U.S. Army Research Laboratory, Adelphi, MD, USA. He is currently interested in machine learning, statistical signal processing, and data mining of large neurophysiological data collections for the development of improved brain–computer interfaces.