Tutorial 5

Date: Monday, December 7, 9:00am to 12:30pm
Speaker: Dr. Danilo Mandic, Imperial College London, UK and Prof. Anthony Kuh, University of Hawaii at Manoa, USA
Title: Advances in Complex Adaptive Signal Processing: Noncircularity, Widely Linear and Kernel Models

Abstract: This tutorial is proposed in response to the growing demand for a material that provides a unified treatment of complex valued adaptive filters and kernel machine learning methods for the processing of general complex signals (circular and noncircular). It brings together recent developments in the statistics of complex variable (augmented statistics) and the powerful framework of CR (Wirtinger) calculus. This offers a number of theoretical performance gains, which is illustrated on simulations using synthetic and real world data, including the noncircular and intermittent radar and wind signals.

The filtering of real world signals requires an adaptive mode of operation to deal with the statistically nonstationary nature of the data, together with feedback and nonlinearity within the architectures to cater for long time dependencies and possibly nonlinear signal generating mechanisms. In the complex domain, real world signals in general do not have rotation invariant statistical distributions (noncircularity), however, standard learning algorithms are optimal only when such distributions are circular. Augmented adaptive filtering and machine learning algorithms, addressed in this tutorial, are based on widely linear models and are suitable for processing both second order circular (proper) and noncircular (improper) complex valued signals.

Using the authors' original research and current established methods, this tutorial provides a rigorous treatment of complex noncircularity and nonlinearity, thus avoiding the deficiencies inherent in several mathematical shortcuts typically used in the treatment of complex random signals. It offers a unified approach to the design of complex valued adaptive filters and kernel machine learning methods, based on augmented complex statistics and the duality between the bivariate and complex calculus.

Key features:

- Offers a comprehensive account of next generation adaptive filtering solutions for the generality of complex valued signals (both circular and noncircular).
- The tutorial will also discuss kernel methods and implementation of online kernel algorithms. For complex processes we show that the implementation of complex augmented processes using kernel methods is simpler and gives better performance than standard complex kernel methods.
- Provides theoretical and practical justification for converting many apparently real valued signal processing problems into the complex domain.
- Derives both gradient descent and nonlinear sequential state estimation algorithms suitable for the processing of noncircular complex signals, such as the augmented CLMS (ACLMS), augmented Affine Projection Algorithm (AAPA), augmented Kalman filter (AKF) and algorithms for IIR and nonlinear structures.
- Discusses implementation of online kernel algorithms: kernel recursive least squares (KRLS) and kernel least mean square (KLMS) algorithms. The KRLS and KLMS algorithms have similarities to RLS and LMS except that the algorithms must also choose to control the number of support vectors and information vectors.
- Addresses the duality between complex and bivariate real adaptive filters and establishes relationships between the corresponding probability distributions.
- Provides a rigorous statistical testing framework for the validity of complex representation and introduces data driven time-frequency decompositions.
- Simulations for both circular and noncircular data sources are included - from benchmark linear and
nonlinear models to real world directional processes such as wind and radar signals, which are made complex by convenience of representation.

Complex valued signals play a central role in the fields of communications, radar, sonar, array, biomedical and environmental signal processing amongst others. This tutorial will have wide appeal to researchers and practicing engineers in these and related disciplines.

**Biography:** Danilo Mandic has been working in the area of adaptive and nonlinear signal processing, and data fusion. His publication record includes more than 200 articles and two research monographs, "Recurrent Neural Networks for Prediction" (with J. Chambers), Wiley 2001 and "Complex Valued Nonlinear Adaptive Filters" (with W. Goh), Wiley 2009. Dr Mandic's work on multichannel signal processing has resulted in an edited a book "Signal Processing for Knowledge Extraction and Information Fusion", Springer 2008. Dr Mandic has given numerous plenary talks and tutorials, including a tutorial at ICASSP 2007 entitled "Fixed Point Theory for Signal Processing and Machine Learning" (with I. Yamada). He is a Reader at Imperial College London, member of EPSRC College, and has been a Member of the IEEE Technical Committee on Machine Learning for Signal Processing, Associate Editor for the IEEE Transactions on Signal Processing, IEEE Transactions on Neural Networks, and IEEE Transactions on Circuits and Systems II. Dr Mandic has been a Guest Professor at KU Leuven Belgium, Tokyo University of Agriculture and Technology, and Frontier Researcher in RIKEN Brain Science Institute, Japan.


Anthony Kuh received his B.S. in Electrical Engineering and Computer Science at the University of California, Berkeley in 1979, an M.S. in Electrical Engineering from Stanford University in 1980, and a Ph.D. in Electrical Engineering from Princeton University in 1987. Dr. Kuh previously worked at AT&T Bell Laboratories and has been on the faculty in Electrical Engineering at the University of Hawaii since 1986. He is currently a Professor and Chair of the department. Dr. Kuh's research is in the area of neural networks and machine learning, adaptive signal processing, sensor networks, communication networks, and renewable energy applications. Dr. Kuh won a National Science Foundation Presidential Young Investigator Award and is an IEEE Fellow. He was also a recipient of the Boeing A. D. Welliver Fellowship and received a Distinguished Fulbright Scholar’s Award working at Imperial College in London. Dr. Kuh was an Associate Editor for the IEEE Transactions on Circuits and Systems, served on the IEEE Neural Networks Administrative Committee, served on the IEEE Neural Networks for Signal Processing Committee, and was a Distinguished Lecturer for the IEEE Circuits and Systems Society. Dr. Kuh co-chaired the 1993 International Symposium on Nonlinear Theory and Its Applications (NOLTA) and served as the technical co-chair for the 2007 IEEE ICASSP both held in Honolulu.