Location: Charlotte Murchison Lecture Theatre (MH_G.26), Kings Buildings, University of Edinburgh

Statistical Signal Processing – Monday 19th June 2023

9:00 to 10:30 Introduction: Introducing exemplar application areas that use statistical signal processing concepts, such as target localization, blind source separation, and other timely topics.

Probability and Random Variables: Axioms of probability and classic paradoxes; scalar and vector random variables; probability transformations and applications; statistical descriptors; central limit theorem.

Classical Estimation Theory: Basic concepts; properties of estimators; maximum likelihood; least squares. The theory will be linked to a "breakdown" of the localization problem.

James Hopgood, University of Edinburgh

10:30 to 11:00 Refreshments

11:00 to 12:30 Further Estimation Theory and Examples: Cramér–Rao lower bounds and Examples; Generative modelling, physical modelling, and Bayesian Estimation Theory.

Overview of Monte-Carlo Methods: Applications for integration and optimization, generating random variables, accept-reject and importance sampling, MCMC techniques.

James Hopgood, University of Edinburgh

12:30 to 13:30 Lunch

13:30 to 15:00 Random Processes: Ensembles, statistical descriptors; input-output system statistics; PSDs; Bayesian Recursions.

James Hopgood, University of Edinburgh

Expectation Propagation (EP) for Scalable Inverse Problems in Imaging: introduction to EP for approximate Bayesian inference, EP scalable solutions to different imaging problems and uncertainty quantification, EP application in low-light-level color imaging using single-photon avalanche diode (SPAD) detector arrays, EP application in turning SPAD arrays into depth-based neuromorphic cameras.

Dan Yao, Heriot-Watt University

15:00 to 15:30 Refreshments

15:30 to 17:00 Decision theory: Risk, optimal decisions, likelihood ratio test, connections with MAP and maximum likelihood estimation, types of errors, and Neyman-Pearson lemma.

João Mota, Heriot-Watt University

17:30 to 19:00 BBQ outside the Nucleus Building

Location: Charlotte Murchison Lecture Theatre (MH_G.26), Kings Buildings, University of Edinburgh

Tracking and Sensing – Tuesday 20th June 2023

9:00 to 10:30 State estimation and multi-target tracking: introduction: Mathematical foundations of tracking and state estimation – transition models, sensor models; Recursive state estimation (Bayes filtering). Single target tracking; the Kalman filter, extended Kalman filter (EKF), unscented Kalman filter (UKF) and particle filter (PF).

Jordi Barr, Dstl

Single target tracking: Introduction to Stone Soup Practicals on Kalman filter, EKF, UKF and PF

Nikki Perree, Henry Pritchett, Dstl

10:30 to 11:00 Refreshments

11:00 to 12:30 Multiple targets, clutter and data association: The issues introduced by ambiguous association, combinatorics; Absolute assignment schemes (nearest neighbour); Probabilistic assignment schemes.

Mengwei Sun, University of Edinburgh

Multiple target tracking: practical session. Data association, multiple targets, PDA and JPDA.

Nikki Perree, Henry Pritchett, Dstl

12:30 to 13:30 Lunch

13:30 to 15:00 Sensor Fusion and Sensor Management: Introduction to sensor fusion, sensor fusion architectures, fusion strategies/algorithms, and real-world challenges. Introduction to sensor management, why it is important, real-world examples, and strategies/implementations for sensor management.

David Cormack, Leonardo

Sensor management: practical session

Nikki Perree, Henry Pritchett, Jordi Barr Dstl

15:00 to 15:30 Refreshments

15:30 to 1700 Practical aspects and simulation – Initiators/Deleters Metrics. Bringing all components together. Practical sessions on initiation/deletion/metrics and complete simulations.

Nikki Perree, Henry Pritchett, Dstl

Advanced Topics

Mengwei Sun, University of Edinburgh; David Cormack, Leonardo

Location: Charlotte Murchison Lecture Theatre (MH_G.26), Kings Buildings, University of Edinburgh

Machine Learning – Wednesday 21st June 2023

9:00 to 11:00 Introduction: Introduction to Machine Learning: Basic concepts; problem formulation and the bias and variance dilemma.

Deep Neural Networks I: Building blocks; theory; and how to train them (aka backpropagation). Compositional view to deep learning and the importance of representations. Risks of the bias variance dilemma, and shortcut learning.

Sotirios Tsaftaris, University of Edinburgh

11:00 to 11:30 Refreshments

11:30 to 13:30 Deep neural networks II: Deep learning on sparse data (incl. techniques such as few-shot meta-learning, self-supervised learning, domain adaptive learning). Robust deep learning for adversarial defense and domain-shift. Uncertainty quantification for XAI.

Henry Gouk, University of Edinburgh

13:30 to 14:30 Lunch

14:30 to 16:30 Resource Constrained Embedded Deep Learning: deployment complexities, optimised models, quantised DNNs, hardware accelerator architectures, real-word examples and demos.

Mehrdad Yaghoobi, University of Edinburgh

19:30 to 22:00 Summer School Dinner at Café Andaluz, George IV Bridge

Location: Charlotte Murchison Lecture Theatre (MH_G.26), Kings Buildings, University of Edinburgh

Source Separation – Thursday 22nd June 2023

9:00 to 10:30 I*ntroduction to array processing*: discussion of applications, signal model, and assumptions; narrowband array processing: steering vectors, angle or arrival (AoA) estimation, and beamformng; narrowband vs broadband passumptions; broadband processing via tap delay lines: broadband AoA estimation via coherent signal subspace methods; formulation of constraints for broadband beamforming and beamforming solutions.

Stephan Weiss, University of Strathclyde

10:30 to 11:00 Refreshments

11:00 to 12:30 *Source separation and beamforming background*: application of linear algebra to array problems, including subspace decompositions, and robust beamforming; adaptive signal processing for beamforming, with application to minimum variance distortion less response beamformer; blind signal separation.

Ian Proudler / Stephan Weiss, University of Strathclyde

12:30 to 13:30 Lunch

13:30 to 15:00 *Introduction to polynomial matrix algebra and applications*: formulation of broadband array problems using polynomial matrix notation; polynomial matrix factorisations; broadband AoA estimation via polynomial matrix techniques; broadband MVDR adaptive beamforming.

Fraser Coutts, University of Edinburgh

15:00 to 15:30 Refreshments

15:30 to 17:00 *Broadband multichannel sensor processing applications*: optimum signal compaction and coding; subspace decompositions with applications: signal enhancement in the signal subspace; transient signal detection in the noise-only subspace.

Stephan Weiss / Ian Proudler, University of Strathclyde