

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

Application: Expectation Propagation (EP) for Scalable Inverse Imaging Problems: introduction to expectation propagation, approximate Bayesian inference, message passing, factor graphs, scalable image restoration, uncertainty quantification, photon-limited imaging.

James Hopgood, University of Edinburgh

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

Networking activity

17:30 to 19:30 BBQ at Kings Buildings

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

James Wright, 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.

Jordi Barr, Dstl

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

James Wright, Dstl

12:30 to 13:30 Lunch

13:30 to 15:00 Practical aspects and simulation – Initiators/Deleters Metrics. Bringing all components together. Practical sessions on initiation/deletion/metrics and complete simulations.

James Wright, Dstl

15:00 to 15:30 Refreshments

15:30 to 17:00 Demonstrations and Advanced Topics –Tracking in video, AIS-based tracking.

Lyudmil Vladimirov, University of Liverpool; David Cormack, Leonardo; James Wright, Dstl



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.

Tim Hospedales, 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-world examples and demos.

Mehrdad Yaghoobi, University of Edinburgh

Networking activity

19:30 Summer School Dinner at Café Andaluz, George IV Bridge, Edinburgh, EH1 1EE.



Source Separation – Thursday 22nd June 2023

9:00 to 10:30 Introduction to Array Processing: Discussion of applications, signal model, and assumptions. Narrowband array processing: steering vectors, angle or arrival (AoA) estimation, and beamforming. 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, 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.

Stephan Weiss and Ian Proudler, University of Strathclyde

15:00 to 15:30 Refreshments

15:30 to 16:30 Exploring the Underwater Environment: applications of beamforming and Bayesian inference to sonar array processing.

Lyudmil Vladimirov, University of Liverpool