UDRC-EURASIP Summer School 2022 Report

The 2022 Summer School was hosted at the University of Edinburgh from 27 June to 30 June 2022. There were 62 people attending from 21 different organisations (48% are from academia, and 52% comes from defence and industry). The topics taught were Statistical Signal Processing, Sensing and Tracking, Machine Learning, and Source Separation and Beamforming. Funding was provided by EPSRC, Dstl and EURASIP. Signal Processing for Defence experts came from University of Edinburgh, Heriot-Watt University, University of Strathclyde, University of Liverpool, Dstl and Leonardo.

Most of the school was taught with lectures and there was time for discussion and questions throughout the day. The Sensing and Tracking day delivered the Stone Soup software and was presented in workshop format and students had an opportunity to use the software. There was also a chance for attendees to get to know each other through a spooky Edinburgh ghost tour and a delicious summer school dinner.



Figure 1. Summer School 2022 Flyer.

Attendees filled in evaluation forms and the overall comments were extremely positive.

Some comments below:

"I would like to thank you for everything. It was a very helpful summer school for me, and I am glad I had a chance to be a part of it".

"I got very useful information that I wouldn't have learned easily elsewhere, and I also met people from both academia and industry. It was a very good event and I will recommend some of the team apply to go next year".

"I found it incredibly useful and having resources like the Stonesoup libraries and the slides in your previous email will be invaluable going forward"

	Monday 27th June -Statistical Signal Processing	Tuesday 28th June – Tracking and Sensing	Wednesday 29th June - Machine Learning	Thursday 30 th June - Source Separation and Beamforming
08:30	Coffee	Coffee	Coffee	Coffee
09:00	Introduction: Introducing exemplar application areas that use statistical signal processing concepts, such as target localization, bindis ource separation, and other thinely topics. Probability and Random Variables: Automs 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. <i>James Hoggod, University of Elinburgh</i>	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, Dati Single target tracking: Introduction to Stone Soup Practicals on Kalman filter, EKF, UKF and PF James Wright, Dati	Introduction to Machine Learning: Basic concepts; problem formulation: data, labels, objective function, constraints, regularization; examples in pattern classification; kernel PCA and KDA, support vector machines, neural networks (NN). Deep Neural Networks 1: Introduction; simple feed forward neural network architecture; how to train neural network; backgroapagation theory; introduction to convolutional neural networks. Sotrivos Tsaftaris, University of Edinburgh	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. Stephon Weiss, University of Strathclyde
10:30	Refreshments / Informal Networking	Refreshments / Informal Networking	Refreshments / Informal Networking	Refreshments / Informal Networking
11:00	Further Estimation Theory and Examples: Carnér–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 Hoggod	Multiple targets, clutter and data association: The Issues introduced by ambiguous association, combinatorics; Absolute assignment schemes (nearest neighbour); Probabilistic assignment schemes. Jord Barr Multiple target tracking: practical session. Data association, multiple targets; PDA and JPDA. James Wright	Deep neural networks II: Deep learning architectures; key factors behind deep learning; residual neural networks; latest developments in neural network architectures. Some applications as examples of deep learning. Sen Wang, Heriot-Watt University	Source Separation and Beamforming Background: Application of linear algebra to array problems, including subspace decompositions, and raby problems, including Adaptive signal processing for beamforming, with application to minimum variance distortion less response beamformer. Ian Prouder, University of Strathclyde
12:30	Lunch / Informal Networking	Lunch / Informal Networking	Lunch / Informal Networking	Lunch / Informal Networking
13:30 14:00	Random Processes: Ensembles, statistical descriptors; input- output system statistics; PSDs; Bayesian Recursions James Hopgood 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. Dan Yao, Heriot-Watt University	Practical aspects and simulation – Initiators/Deleters Metrics. Bringing all components together. Practical sessions on initiation/deletion/metrics and complete simulations. James Wright	Deep Neural Networks III: Deep learning on sparse data using meta-learning and self- supervised learning. Robust deep learning for adversarial defense and domain-shift. Some practical examples in vision, language and control. Henry Gouk, University of Edinburgh	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
15:00	Refreshments / Informal Networking	Refreshments / Informal Networking	Refreshments / Informal Networking	Refreshments / Informal Networking
15:30	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-Wott University Summary and Conclusions of Key Poins from the Day. João Mota and James Hopgood.	Demonstrations and Advanced Topics -Tracking in video, Als-based tracking. Lyudmil Vladimirov, University of Uverpol; David Cormack, Leonardo; James Wright	Resource Constrained Embedded Deep Learning: deployment complexities, optimised models, quantised DNNs, hardware accelerator architectures, real-word examples and demos. Mehrdad Yaghoobi, University of Edinburgh	Exploring the Underwater Environment: applications of beamforming and Bayesian inference to sonar array processing. Lyudmil Vladimirov, University of Liverpool Close 16:30
17:00	Close			

Figure 2. Programme.



Figure 3. Attendees of the Summer School.