UDRC-EURASIP Summer School Programme – 2021

	Monday 28th June -Statistical Signal Processing	Tuesday 29th June – Tracking and Sensing	Wednesday 30th June - Machine Learning	Thursday 1st July - 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, 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***	**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 ***Steve Hiscocks, Dstl***	**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 I:** Introduction; simple feed forward neural network architecture; how to train neural network; backpropagation theory; introduction to convolutional neural networks. ***Sotirios Tsaftaris, University of Edinburgh***	**Introduction to Array Processing:** Discussion of applications, signal model, and assumptions. Narrowband array processing: steering vectors, angle or arrival (AoA0estimation, 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***
10.00				
10:30	Refreshments	Refreshments	Refreshments	Refreshments
11:00	**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***	**Practical session – continued. Multiple targets, clutter and data association:** The issues introduced by ambiguous association, combinatorics; Absolute assignment schemes (nearest neighbour); Probabilistic assignment schemes. **Multiple target tracking: practical session.** Data association, multiple targets, PDA and JPDA. ***Jordi Barr, Steve Hiscocks***	**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 robust beamforming. Adaptive signal processing for beamforming, with application to minimum variance distortion less response beamformer. ***Ian Proudler, University of Strathclyde***
12:00				
12:30	Lunch	Lunch	Lunch	Lunch
13:30	**Random Processes:** Ensembles, statistical descriptors; input-output system statistics; spectral representations. **Short talks on Advanced topics: Including:** Bayesian Recursions and Particle Filtering Methods; Introduction to Hypothesis Testing and Detection Theory. ***James Hopgood and João Mota, Heriot-Watt University***	**Multiple target tracking: practical session – continued.** Practical aspects and simulation –Initiators/Deleters Metrics. Bringing all components together. Practical sessions on initiation/deletion/metrics and complete simulations. ***Steve Hiscocks, Jordi Barr***	**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**.** ***Tim Hospedales, 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***
14:00				
15:00	Refreshments	Refreshments	Refreshments	Refreshments
15:30	**Short talks on Advanced topics: Including:** Sparsity in Signal Processing; Optimal Detection of Signals and other Applications. ***João Mota, Heriot-Watt University*** **Summary and Conclusions of Key Points from the Day.** ***João Mota and James Hopgood.***	**Demonstrations and Advanced Topics** –Tracking in video, AIS-based tracking ***Lyudmil Vladimirov, University of Liverpool; David Cormack, Leonardo; Steve Hiscocks***	**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. ***Jason Ralph, University of Liverpool***
17:00	**Close**			