UDRC Summer School Programme – 2022

	Monday 27th June -Statistical Signal Processing	Tuesday 28th June – Tracking and Sensing	Wednesday 29th June - Machine Learning	Thursday 30th June - Source Separation and Beamforming
08:30	Coffee	Coffee	Coffee	Coffee
09:00 / 10.00	**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 (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	Refreshments / Informal Networking	Refreshments / Informal Networking	Refreshments / Informal Networking	Refreshments / Informal Networking
11:00 / 12:00	**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*	**Multiple targets, clutter and data association:** The issues introduced by ambiguous association, combinatorics; Absolute assignment schemes (nearest neighbour); Probabilistic assignment schemes. *Jordi Barr* **Multiple target tracking: practical session.** Data association, multiple targets, PDA and JPDA. **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*
12:30	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; 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*	**Practical aspects and simulation** – Initiators/Deleters Metrics. Bringing all components together. Practical sessions on initiation/deletion/metrics and complete simulations. *Steve Hiscocks*	**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*
15:00	Refreshments / Informal Networking	Refreshments / Informal Networking	Refreshments / Informal Networking	Refreshments / Informal Networking
15:30	**Advanced topics:** Sparsity in Signal Processing; Lasso, generalisations, and 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**			

Timings will be UK time. There will be a networking event on Monday at 17:00 until 19:00 and a Summer School dinner on Wednesday at 19:30.