IMPERIAL

Module Specification

Basic details

UID		Cohorts covered	Earliest cohort:	Latest c:
Long title	Adaptive Signal Processing and Machine Intelligence			
New code	ELEC70001	New short title		

Brief description of module *(approx. 600 chars.)*

Many areas in engineering, biomedicine and finance increasingly rely on learning algorithms that operate iteratively and/or in real-time, in order to solve problems that are not amenable to classic techniques. This module aims to equip you with a strong theoretical foundation and comprehensive understanding of modern machine intelligence methods that underpin adaptive signal processing, neural and deep neural networks, and big data analytics. Particular emphasis is placed on the interpretability, efficiency, and scalability of such learning machines, and on time series and streaming data applications.
You will gain hands-on experience through structured MATLAB or Python assignments based upon adaptive acoustic noise cancellation, high-resolution inference from your own physiological recordings (ECG), inference from EEG, adaptive frequency tracking in applications such as communications, finance and brain computer interface, data augmentation for deep learning, use of domain knowledge to design intepretable and efficient neural networks, and Big Data applications.

1079 characters

Available as a standalone module/ short course? No

Statutory details

	ECTS	CATS	Non-credit
Credit value	5	10	N
FHEQ level	L7		

HECOS codes:

Allocation of study hours

	Hours	
Lectures	20	
Group teaching	0	*Incl. seminars, tutorials, problem classes.*
Lab/ practical	0	
Other scheduled	10	*Incl. project supervision, fieldwork, external visits.*
Independent study	95	*Incl. wider reading/ practice, follow-up work, completion of assessments*
Placement	0	*Incl. work-based learning and study that occurs overseas.*
Total hours	125	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? No

Module delivery

Delivery mode	Taught/ Campus	Other	
Delivery term	Term 2	Other	

Ownership

Primary department	Department of Electrical and Electronic Engineering
Additional teaching departments	None
Delivery campus	South Kensington

Collaborative delivery

Collaborative delivery?	0

External institution	
External department	
External campus	

Associated staff

Role	CID	Given name	Surname
Lecturer		Danilo	Mandic
		0	0
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Learning and teaching

Module description

Learning outcomes

By the end of this module, you will be able to:
1. **Analyse** real-world time-series and multidimensional data to identify structure, latent components, and patterns relevant to inference tasks.
2.**Design and implement** adaptive signal-processing and machine-learning models suitable for real-time time series or streaming data.
3. **Develop and evaluate** computationally efficient machine-intelligence models, including feedforward, recurrent, convolutional, deep, and encoder–decoder neural networks.
4.**Employ** the geometry of learning and domain knowledge to design interpretable learning machines.
5. **Apply** tensor decompositions for big data analysis and super-compression of neural networks.
6. **Develop and implement** adaptive machine-intelligence solutions, for applications in statistical inference, data augmentation, and tensor-based model compression.

Module content

Finding latent components in data, dimensionality reduction through recursive principal component analysis (PCA), principal component regression (PCR) and projection on latent spaces (PLS). Applications in spectral estimation (MUSIC, Pisarenko) methods, real-time time-frequency estimation, and data augmentation for deep learning. Adaptive filtering algorithms: least mean square (LMS) and recursive least squares (RLS). Intuition behind Kalman filtering and links with LMS and RLS. Applications in time series prediction, adaptive noise cancellation, equalisation and source separation. Adaptive regularisation, robust adaptive estimation, dealing with sparsity, LASSO, elastic net, bias-variance considerations in adaptive inference. Complex-valued learning machines, augmented complex statistics, widely linear models, and complex valued neural networks. Universal function approximation through neural networks, learning algorithms for feedforward and recurrent neural networks, convolutional neural networks and deep learning. Neural networks for time series prediction. Demystifying neural and convolutional neural networks, use of domain knowledge to design interpretable and efficient neural networks. Unsupervised neural networks, Hebbian learning, encoder-decoder networks, autoencoders, and elements of Generative Artificial Intelligence. Tensors for Big Data analysis, mitigating the curse of dimensionality, computation of tensor decompositions. Use of tensors for the design of super-compressed and efficient deep neural neworks.
Case studies

Learning and Teaching Approach

The module will be delivered primarily through lectures introducing the key concepts and methods, and will be supported by a variety of delivery methods combining the traditional and the technologically advanced ones. The content is presented via a combination of slides, whiteboard analysis, and practical demonstrators. The lectures will be in person, online and also recorded. Learning will be reinforced through hands-on in-class lab sessions. You will be provided with lecture notes, problem and answer sets, and coursework assignments. The course is assessed by coursework (see Assessment Strategy).

Assessment Strategy

Assessment strategy: Coursework assignments, whose individual scores yield 90% of the final mark. The remaining 10% is awarded for clarity of presentation and organisation.

Feedback

You will first submit Assignment 1 and receive feedback, which will serve as guidance for the remainder of the Coursework. You will also receive help during the GTA sessions.
You will receive cohort-level feedback, once the full Coursework is marked. Additional individual feedback will be available on request.

Reading list

1) Hayes, M.H.: Statistical Digital Signal Processing and Modelling, Wiley, 2006.
2) Mandic, D.P., & Goh, V.S.L.: Complex Valued Nonlinear Adaptive Filters: Noncircularity, widely linear and neural models, 2009
3) Mandic, D.P. & Chambers, J. A. "Recurrent Neural Networks for Prediction", Wiley, 2001.
4) Cichocki, A., Mandic, D. P. et al. "Tensor Decompositions for Signal Processing Applications", Now Publishers, 2017.
[5] Kanna, S. Mandic, "Bringing wearable sensors into the classroom: A participatory approach", IEEE Signal Processing Magazine, vol. 35, no. 3, pp. 110-130, 2018.

Quality assurance

Date of first approval	
Date of last revision	November 2025
Date of this approval	April 2026
Module leader	Prof Danilo Mandic
Notes/ comments	Initial revision Nov 2025; changes made in May '26 following PC comments

Office use only

QA Lead	
Department staff	
Date of collection	
Date exported	
Date imported	

Assessment details

Grading method	Numerical	Pass mark	50%

Assessments

Assessment type	Assessment description	Weighting	Pass mark	Must pass?
Coursework	Matlab/Python Experiment 1: Latent component analysis applied to spectrum estimation, robust regression, and data augmentation for deep learning	20%	50%	N
Coursework	Matlab/Python Experiment 2: Linear learning machines and adaptive signal processing	20%	50%	N
Coursework	Matlab/Python Experiment 3: Complex valued learning machines and widely linear modelling	15%	50%	N
Coursework	Matlab/Python Experiment 4: Intepretable deep and convolutional neural networks	20%	50%	N
Coursework	Matlab/Python Experiment 5: Big data analytics with multi-linear tensor networks	15%	50%	N
Coursework	Presentation and organisation of the report	10%	50%	N
0	0	0%	0%	0.00
0	0	0%	0%	0.00
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		100%		