Course descriptor B31XO

Course code	**B31XO**
Course title	Scalable Inference & Deep Learning I
Credits	15
School	Engineering and Physical Sciences
SCQF Level	11
Semester	1
Aims	What is the most efficient way to sense, or sample signals that we want to observe? Once data have been acquired, how do we retrieve the sought signal from these acquired data? Such "inference" or "inverse" problems are core to Data Science, particularly when the size of the signal is large and the "inference algorithms" need to be "scalable". This module approaches these questions both from a theoretical perspective (underpinned by the theories of compressive sensing, convex optimisation, deep learning) and in the context of "computational imaging" applications in a variety of domains ranging from astronomy to medicine. **Itemised list:** • Introduce the interconnected problematics of data acquisition and image recovery in computational imaging. • Study the theory of compressive sampling proposing nonconventional sub-Nyquist sampling approaches and related approaches for accurate signal recovery from partial data. • Study the theory of convex optimisation offering scalable algorithmic structures for reconstruction of signals and images from partial data. • Explore how machine learning algorithms (more specifically deep neural networks) can provide an alternative framework to solve imaging inverse problems, or otherwise integrate and enhance optimisation algorithms. • Study computational imaging applications with scientific and industrial relevance.
Syllabus	General course content description: The first part of the course will be taught. We will review the basic notion of Nyquist sampling of signals and rapidly dive into "computational imaging". In this context, mathematical algorithms need to be designed to solve an "inference" or "inverse" problem for image recovery from incomplete data. The size of the variables of interest in modern imaging application (e.g. in astronomy or medicine) can be very large. In our journey, and concentrating on the data processing (rather than hardware, or application) aspects, we will learn the basics of the theories of compressive sensing (which tells us how to design intelligent data acquisition schemes for sub-Nyquist sampling) and

	convex optimisation (which provides a whole wealth of algorithms capable to solve inverse problems, and scalable to high-dimensional problems). The second part of the course will take the form of a project which will enable us to explore how machine learning algorithms (more specifically deep neural networks) can provide an alternative framework to solve inverse problems (in particular for imaging applications), or otherwise integrate and enhance optimisation algorithms. **Itemised list of subjects covered:** - Compressive sensing: motivation for compressive sensing; concepts of sparsity, incoherence, and randomness; theorems for l1 recovery. - Convex optimisation: convex problem and optimality conditions; proximal operators; Forward backward algorithm; Alternating Direction Method of Multipliers algorithm. - Deep learning: deep neural networks (in particular convolutional neural networks), network architecture, training & testing, networks for end-to-end inference, networks in optimisation algorithms. - Applications to computational imaging.

Learning Outcomes	
Subject Mastery	Understanding, knowledge and cognitive skills Critical understanding of the theory of compressive sensing and its application in computational imaging - Critical understanding of the theory of compressive sensing. - Critical understanding of the theory of convex optimisation. - Critical understanding of deep learning. - Practical knowledge of computational imaging. - Practical knowledge of optimisation algorithms and deep neural networks. Scholarship, enquiry and research (Research Informed Learning) - Practical knowledge of recent advances in signal processing theory and their applications for the development of computational imaging algorithms, e.g. for medical imaging applications. - Understanding of hot topics in Data Science research.
Personal Abilities	Industrial, commercial and professional practice - Ability to design efficient sampling/sensing strategies in imaging applications (e.g. medical imaging).

	- Ability to design efficient algorithms to solve inverse problems in imaging applications (e.g. medical imaging). Autonomy, accountability and working with others - Practical experience of both individual and team work under strict deadlines. - Practical experience of project and people management. Communication, numeracy and ICT - Practical experience of oral communication.

Assessment method	100% course work