Course descriptor B31XO

Course code	B31XO
Course title	Sampling and Computational Imaging
Credits	15
School	Engineering and Physical Sciences
SCQF Level	11
Semester	1
Aims	• Introduce the general concept of inverse problems for computational imaging and optimisation tools to solve them • Study imaging applications with scientific and industrial relevance. The majority of the module (around 2/3rd) will be dedicated to 'Compressive sensing and imaging'. In many applications signals are firstly acquired at Nyquist rate before being adaptively compressed for storage or transmission. Our ability to merge acquisition and compression into a non-adaptive methodology where signals would be sensed in a compressive form would open the door to applications where full data acquisition is not accessible in the first place, because it is too costly, to slow or requires too much bandwidth. But is it possible to sense/sample signals compressively? In this context an ill-posed inverse problem arises in the perspective of signal recovery. The recent theory of compressive sensing demonstrates that a large class of signals may in fact be accurately recovered from sub-Nyquist sampling. The sampling strategy must follow specific randomness and incoherence conditions. The signals of interest must be sparse in some linear transform domain. The theory also provides tractable algorithms to solve the associated linear inverse problem, designed in the context of convex optimisation, and more specifically relying on l1 minimisation. The module will study the basic theory of compressive sensing for signals defined on the Euclidean manifold. It also introduces the basic theory of convex optimisation and modern optimisation algorithms. Laboratories are dedicated to algorithm implementation in a quite generic application setting. A later part of the module (around 1/3rd) will take the form of a project providing more 'hands on' experience on sampling and computational imaging. Extending beyond the specific remit of compressive sensing and convex optimisation, the project will enable the student to investigate nonconvex optimisation algorithms, or Bayesian inference algorithms for applications such as joint calibration and imaging, source separation, etc., mainly for real imaging problems, for example in astronomy or medicine. When suitable, students will be offered some additional short courses on selected topics in sampling and computational imaging. Examples of topics range from (i) sampling and computational imaging on non-Euclidean manifolds (e.g. graphs), to (ii) Bayesian inference for imaging inverse problems, etc

Syllabus	• Compressive sensing: Motivation for compressive sensing in the context of Euclidean imaging applications in medicine and astronomy; 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 (ADMM algorithm) • Computational imaging project: Nonconvex optimisation algorithms; Bayesian inference algorithms; applications such as joint calibration and imaging, source separation, etc., mainly for real imaging problems, for example in astronomy or medicine. • Possible short courses (in support to the project when suitable): sampling and computational imaging on non-Euclidean manifolds (e.g. graphs); Bayesian inference for imaging inverse problems, etc.

Learning Outcomes	
Subject Mastery	Understanding, Knowledge and Cognitive Skills • Compressive sensing: Motivation for compressive sensing in the context of Euclidean imaging applications in medicine and astronomy; 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 (ADMM algorithm) Scholarship, Enquiry and Research (Research-Informed Learning) • Computational imaging project: Nonconvex optimisation; Bayesian inference; Calibration and imaging, source separation, etc. • Short courses (in support to the project): Examples of topics range from (i) sampling and computational imaging on non-Euclidean manifolds (e.g. graphs), to (ii) Bayesian inference for imaging inverse problems, etc
Personal Abilities	Industrial, Commercial and Professional Practice • To provide the student with tools to design efficient sampling/sensing strategies in imaging applications (compressive sampling or more general inverse problems) • To provide the student with tools to design efficient reconstruction strategies in imaging applications (convex/nonconvex optimisation or Bayesian inference)

Assessment method	100% course work