MEDICAL IMAGING COURSE SYLLABUS

Course 3

Image Theory, perception and processing

Monday 23 (PM) - Tuesday 24 February 2025 (1.5 days)

Syllabus: 9.5 hours of educational content

Image Theory, Perception and Processing

A one and a half day course module on the underpinning theory of medical imaging, including the mathematics of formation, image processing and human visual perception. The course has been extended to cover machine learning and AI imaging applications, including practical exercises that demonstrate the AI/ML concepts introduced in the lectures. Much of the material in this course is generally applicable to all types of imaging system. Illustrations and examples from medical imaging will be used throughout including ultrasound, nuclear medicine, MRI and x-ray CT.

Day One

Fundamentals of Image Formation
Lecturer: Dr Matt Blackledge

Image representation – Colour spaces, image digitization, Fourier theory and convolution.

Imaging systems – linear systems, point spread function and transfer functions.

Sampling theory – finite apertures and the sinc function. Nyquist rate and Whittaker-Shannon theory. Sampling artefacts, aliasing pre- and post-sample blurring.

Image compression – Discrete cosine transform, Wavelet transforms

Noise – fixed pattern noise, Poisson noise, Johnson noise and nonlinearity. Introduction to image enhancement and filtering – point operators, spatial operators and transform operators.

Perception and Interpretation of Medical Images
Lecturer: Mr Mark O'Leary

The abilities and limitations of the human vision.

Contrast discrimination, spatial discrimination and image noise.

Image display systems – controls and gamma characteristics.

Experimental methods of assessing man & machine performance – ROC analysis, contrast detail tests etc.

Three-Dimensional Image Display
Lecturer: Ed McDonagh

Methodology of 3D display.

Day Two

Image Processing Techniques

Lecturer: Dr John Suckling

Image processing systems – design principles; engineering a solution; practical skills

Medical imaging data – physical sources; information contained in images; single value/multiple valued data; a brief history.

Enhancing images for viewing – contrast (grey-level transformations); thresholding; colour scales; histogram equalisation. Applying a moving window: adaptive thresholding.

Image analysis/Feature extraction – what are features and how are they calculated (convolution filtering)? texture; edges and boundaries; shape and structure.

Dimensional reduction methods – principal component analysis, factor analysis.

Classical classifiers – supervised vs unsupervised; supervised: Baysian classifier; unsupervised: k-means; the n > p problem and overfitting, amplified sensitivity, and multicollinearity.

Deep Learning Fundamentals

Lecturer: Dr John Suckling

A brief history of Machine Learning – origins; modelling the mind (expert systems, Cyc) vs the brain (perceptrons, MLPs); supervised vs semi-supervised vs unsupervised; machine learning and medical imaging.

Supervised machine learning – the perceptron; support vector machines; convolutional neural networks; transformers and large language/vision models.

Semi-supervised – motivation; automatically labelling data.

Unsupervised – autoencoders.

Machine learning howto – datasets; learning, validating, and testing; k-fold cross-validation; hold-out validation; explainable AI.

Responsible AI

Lecturer: Dr John Suckling

Ethical foundations – ethical frameworks (deontological, utilitarian, virtue); safety, fairness (non-discrimination), accountability, and transparency; informed consent.

Bias – bias in datasets; bias in algorithms; impacts; explainability vs interpretability.

Governance and legal – data protection; privacy; compliance and accountability.

Responsible AI howto – ethics impact assessments; model testing; stakeholder engagement; audits.

Generative AI
Lecturer: Dr Matt Blackledge

What is generative AI?

Transformers – Why important, the transformer block.

Query, Key, Value (QKV) – Data embeddings, scaled dot-product attention
Attention: The attention mechanism, self-attention, and token generation.

Prompt engineering basics – What you ask matters!

Practical exercises
Lecturers: Dr John Suckling and Dr Matt Blackledge

End-to-end image classification with convolutional neural network.

Transfer learning for lightweight classification tasks.

Introduction to image segmentation with lightweight, patch-based UNets.