

Independent PhD course: Theoretical image science 4 credits

(Swedish: Teoretisk bildvetenskap)

This is an independent PhD course (third cycle) without a course code. Upon passing the course, the examiner will issue a certificate and the course will be entered into Ladok using the “Transfer of course credits” mechanism.

Examiner

Mats Persson

Department of Physics, KTH

Intended learning outcomes

After completion of the course, the student should be able to

- at least one of the following:
 - use linear-systems theory to describe and evaluate the performance of an imaging system.
 - suggest physics-based models for the noise properties of common imaging systems.
 - account for differences between different types of imaging systems and suggest suitable performance measures for these.
 - develop and evaluate an image reconstruction method adapted to a given imaging system using numerical programming.
- plan, perform and critically evaluate an experiment to measure the performance of an imaging system.
- independently apply methods from image science to analyze a scientific or engineering problem.

At the end of the course, the student’s knowledge of these topics will be deep enough that the student is able to follow and contribute to cutting-edge research in imaging systems analysis.

Course content

Image-forming devices are used in many areas of science and technology and can take different forms such as cameras, telescopes, microscopes, medical imaging devices etc. Despite this wide range of applications, there are a number of common methods that are useful for anyone involved in the development or characterization of imaging systems. This course gives an introduction to the techniques that have been developed for measuring and enhancing the performance of imaging systems, in order to provide understanding of how image quality is determined by an interplay between hardware and data processing. Focus lies on studying generally applicable methods, but we will also study how these techniques can be applied to a variety of imaging modalities. The course may be of interest for students of biophysics, medical imaging, astronomy, optics, nanotechnology and other fields who are interested in the design and characterization of imaging systems.

The following topics are covered:

- Types of imaging tasks: detection and quantification
- Statistical decision theory and the ideal observer. The ideal linear observer
- Receiver operating characteristics (ROC).

- Contrast-to-noise ratio (CNR): applications and limitations
- Fourier transforms and linear systems
- Signal transfer in imaging systems: point-spread function (PSF) and modulation transfer function (MTF).
- Noise modelling in imaging systems.
- Random processes. Autocorrelation and noise power spectrum (NPS).
- Aliasing in imaging systems: impact on signal and noise
- The ideal linear observer for linear shift-invariant systems.
- Detector performance measures: noise equivalent quanta (NEQ) and detective quantum efficiency (DQE).
- Subjective and objective image quality measures. Observer studies.
- Numerical observers
- The Cramer-Rao lower bound.
- Analytical image reconstruction: Fourier inversion, filtered backprojection.
- Variational image reconstruction. Regularization and its effect on the image.
- Multichannel imaging. Time-resolved imaging.
- Image reconstruction based on machine learning.

Recommended prerequisites

Recommended prerequisites: Fourier transforms, basic probability and statistics and numerical programming using Matlab, numPy or similar. A course about linear systems is advisable but not necessary.

Course literature

Harold L. Kundel, Jacob Beutel and Richard L. van Metter, "Handbook of Medical Imaging", vol. 1-2 (SPIE press)

Examination

A project, presented with a written report and an oral presentation.