OPTI 536, Introduction to Image Science
Syllabus, Spring 2022

This course presents the basic theoretical principles of image science and its application in the description and analysis of imaging systems, including examples in microscopy, medical imaging, remote sensing, and astronomy. The course provides an introduction to mathematical representations of objects, continuous and discrete mappings from objects to image data, and the analysis of systems to determine measurement and null spaces, ie what features of the object the imaging system is sensitive to and what it is blind to. This course is intended for graduate students in optical sciences or engineering with an appropriate mathematical background at the level of advanced calculus. The course is organized into 4 key topic areas:

Unit I: Mathematical formalism of image science
- Overview of modern imaging and image formation
- Objects as vectors in a vector space, image formation as a continuous to continuous or continuous to discrete mapping from an object vector space to an image vector space
- Eigenfunctions, linear systems, Fourier transforms
- Indirect imaging, inverse problems, iterative algorithms

Unit II: Optics of imaging
- Geometrical optics description of imaging, radiometry
- Physical optics description of imaging
- Coherent and incoherent imaging, diffraction limit
- Digital imaging, sampling, image detectors, displays
- Image processing

Unit III: Examples of imaging systems
- Optical and electron microscopy
- Advanced optical microscopy, optical coherence tomography, near-field imaging
- Imaging in astronomy and remote sensing
- Radar, Lidar
- Sonar, ultrasound imaging
- Shadow casting, coded apertures
- X-ray imaging, computed tomography
- Nuclear imaging, SPECT, PET
- Magnetic resonance imaging

Unit IV: Observers and task-based image quality assessment
- Noise in imaging systems
- Classification and estimation tasks, ideal observer
- Image quality, task-performance evaluation

Learning objectives:
Upon completion of this course, students will
- be able to identify what object property is measured, how the imaging system collects the data, and how the data are processed to create images for each of the imaging systems covered in the course, and recognize important applications of each technique;
- be able to discuss analysis of imaging systems via singular value decomposition, how it divides objects into measurement and null components, and how it leads to the concept of the pseudo-inverse; and
- be able to explain why image quality is best assessed in terms of the ability to perform well-defined tasks.