NPRE 435: Radiological Imaging

Instructor: Professor Ling-Jian Meng

Meeting Schedule/Contact Hours: Three 50-minute lecture-discussions (3.0 contact hours) per week.

Objectives:

This course is designed to introduce the physical, mathematical, and experimental foundation of radiological image techniques and their applications in diagnostic radiology and nuclear security. During the first half of the course, we will discuss linear system theory and tomographic image processing techniques, radiation sources for diagnostic imaging and radiation therapy, the interaction of ionizing radiation, imaging sensor technologies, and image formation techniques. The second half of the course will focus on the standard radiological imaging modalities, including X-ray computed tomography (CT), single-photon emission computed tomography (SPECT), positron emission tomography (PET), and their applications in clinical radiology and radiation therapy. We will also discuss emerging imaging techniques that explore complex nuclear physics phenomena, such as the temporal and angular correlation of X-ray and gamma-ray emissions, positronium lifetime, and quantum entanglement of annihilation photons.

Topical Outline

Introduction to Radiological Imaging	2 hours
Chapter 1: Mathematical Preliminaries for Radiological Imaging	
1.1 Signals and systems	2
1.2 Fourier transform basics and sampling theory	
1.3 Analytical image reconstruction methods	4
1.4 Statistical image reconstruction methods	3
1.5 Image quality assessment	2
Chapter 2: Introduction to Physical Principles	
2.1 Typical radiation sources for radiological imaging and radiation therapy	1.5
2.2 Spatial, spectral, and temporal characteristics of X-ray and gamma-ray emissions	1.5
2.2 Interactions of ionizing radiation with matter	2
Chapter 3: X-ray Radiography and Computed Tomography	
3.1 Basic principles, current implementations, and future trends of X-ray generators	1
3.2 X-ray imaging sensors	2
3.3 Planar radiography and X-Ray computed tomography (CT)	2
3.4 Neutron and charged-particle transmission CT	1
Chapter 4: Emission Tomography I: Standard Modalities for Diagnostic Radiology	
4.1 The tracer principle in emission tomography and radionuclide therapy	1
4.2 Gamma-ray imaging sensor technologies	3
4.3 Single-photon emission computed tomography (SPECT)	2
4.4 Positron emission tomography (PET)	2

Lab tour 2

Chapter 5: Emission Tomography II: Emerging Imaging Technologies

5.1 Positronium lifetime tomography
5.2 Imaging techniques exploring the spatial-spectral-temporal correlations of gamma-ray emissions 1
5.3 Imaging techniques exploring the quantum entanglement of annihilation gamma-rays 1

Term project presentation 1

Total: 37 hours

Textbooks

Required textbook:

[1] Medical Imaging Signals and Systems, J. Prince and J. M. Links, Second Edition, Pearson Prentice Hall, 2013.

Recommended reading:

[1] Foundations of Imaging Sciences, H Barrett, John Wiley & Sons, 2006.

[2] Foundations of Medical Imaging, Z. H. Cho, John Wiley & Sons, 1993.

[3] Radiation Detection and Measurements, Third Edition, G. F. Knoll, John Wiley & Sons, 1999.

[4] Elements of Modern X-ray Physics, Second Edition, J Als-Nielsen, Des McMorrow.

Grading: Homework (40%), Quizzes (15% total), Term Projects (15%), Midterm and Final Exams: 30%.