Rochester Institute of Technology
Rochester, New York

COLLEGE of SCIENCE
Center for Imaging Science

Noise and Random Processes 1051-713

1.0 Title: Noise and Random Processes
Date: October 25, 2006
Credit Hours: 4
Prerequisite(s): 1051-716, 718, 719 or permission of instructor.

2.0 Course information:

	Contact hours	**Maximum students/section**
Classroom	4	30
Lab		
Studio		
Other (specify ________)		

Quarter(s) offered (check)
______**Fall** ______**Winter** __X___**Spring** _____**Summer**

Students required to take this course: (by program and year, as appropriate)
Graduate students in Imaging Science, PhD track.

Students who might elect to take this course:
Graduate students in Imaging Science, MS track. Graduate students in the College of Science or College of Engineering.

3.0 Goals of the course (including rationale for the course, when appropriate)
Provide students with a basic knowledge foundation that enables him/her to describe signals and noise in imaging systems, and to apply this knowledge to the optimization of S/N in imaging systems.

4.0 Course description (as it will appear in the RIT Catalog, including pre- and co-requisites, quarters offered)

1051-713 Probability, Noise, and System Modeling

The purpose of this course is to develop an understanding and ability in modeling noise and random processes within the context of imaging systems. The focus will be on stationary random processes in both one dimension (time) and two dimensions (spatial). Power spectrum estimation will be developed and applied to signal characterization in the frequency domain. The effect of linear filtering will be modeled and applied to signal detection and maximization of SNR. The matched filter and the Wiener filter will be developed. Signal detection and amplification will be modeled, using noise figure and SNR as measures of system quality. At completion of the course, the student should have the ability to model signals and noise within imaging systems.**Class 4, Credit 4 (S)**

5.0 Possible resources (texts, references, computer packages, etc.)

5.1 Peebles, *Probability, Random Processes, and Random Signals, 4th Ed.*
5.2 Instructor's Course Notes.

6.0 Topics

6.1 Probability
- 6.1.1 Introduction to probability
- 6.1.2 Joint and conditional probability
- 6.1.3 Independent events
- 6.1.4 Combined experiments
- 6.1.5 Bernoulli trials

6.2 Random Variables
- 6.2.1 Random variable (RV) concept
- 6.2.2 Distribution function
- 6.2.3 Density function
- 6.2.4 Gaussian RV
- 6.2.5 Density and distribution examples
- 6.2.6 Conditional distribution and density functions

6.3 Operations on One RV – Expectation and Moments
- 6.3.1 Expectation
- 6.3.2 Moments
- 6.3.3 Functions that give moments

6.4 Multiple RVs
- 6.4.1 Vector RVs
- 6.4.2 Joint distribution and its properties
- 6.4.3 Joint density and its properties
- 6.4.4 Conditional distribution and density
- 6.4.5 Statistical independence
- 6.4.6 Distribution and density of a sum of RVs
- 6.4.7 Central limit theorem

6.5 Operations on Multiple RVs

- 6.5.1 Expected value of a function of RVs
- 6.5.2 Conditional expectation
- 6.5.3 Jointly Gaussian RVs
- 6.5.4 Sampling and limit theorems

6.6 Random Processes – Spatial/Temporal Characteristics

- 6.6.1 Random process (RP) concept
- 6.6.2 Stationarity and ergodicity
- 6.6.3 Correlation and covariance functions
- 6.6.4 Discrete RPs and sequences
- 6.6.5 Cyclostationary RPs
- 6.6.6 Image noise and its analysis

6.7 Random Processes – Spectral Characteristics

- 6.7.1 Power density spectrum and its properties
- 6.7.2 Relationship between power spectrum and autocorrelation function
- 6.7.3 Power spectrums for discrete RPs
- 6.7.4 White noise
- 6.7.5 Photon noise
- 6.7.6 Response of linear systems to random signals
- 6.7.7 Zero-frequency value of noise power spectrum
- 6.7.8 Noise correlation

6.8 Zero-Frequency Analysis of Signal and Noise

- 6.8.1 Photon noise and signal-to-noise ratio
- 6.8.2 Noise sources in digital imaging
- 6.8.3 Detector performance metrics
- 6.8.4 Example: System radiometric performance analysis
- 6.8.5 Example: Photon amplifier modeling

6.9 Fourier Analysis of Signal and Noise

- 6.9.1 System performance metrics
- 6.9.2 Signal and noise transfer
- 6.9.3 Cascaded systems
- 6.9.4 Example: Electro-optical system
- 6.9.5 Example: Radiographic screen-detector system

6.10 Fourier Analysis of Signal and Noise in Digital Systems

- 6.10.1 Detector-element size and aperture modulation transfer function (MTF)
- 6.10.2 Digital MTF: presampling MTF and aliasing
- 6.10.3 Digital Wiener spectrum: presampling and noise aliasing
- 6.10.4 Digital DQE
- 6.10.5 Example: digital detector array performance analysis

7.0 Intended learning outcomes and associated assessment methods of those outcomes

Learning Outcome	In class attendance and evaluation	Homework Assignments
7.1 Ability to apply basic probability theory to solving problems	X	X
7.2 Use the random process concept to solve problems	X	X
7.3 Analysis of signal and noise in imaging systems	X	X
7.4 Optimization of signal/noise in imaging systems	X	X

8.0 Program or general education goals supported by this course

8.1 Satisfies one element of core course requirements for PhD in Imaging Science.

8.2 Prepares graduate students in science and engineering for careers in imaging science.

9.0 Other relevant information (such as special classroom, studio or lab needs, special scheduling, media requirements, etc.)

9.1 Classroom with computer projection system, internet access and conference telephone access for online participation.

10.0 Supplemental information - NONE