Course Syllabus

1051-713 Noise and Random Processes

Course:
SIMG-713 Noise and Random Processes
Four (4) credit hours
Four (4) lecture hours per week
Prerequisites: 1051-716, 718, 719 or permission of instructor

Course Description:
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 initial part of the course is an introduction/review of basic probability theory needed for the middle part of the course, which introduces random processes. Much of this part of the course will focus on the temporal dimension, as that dimension is what is emphasized in the textbook. The final part of the course will demonstrate the application of the textbook material to the understanding of signal and noise in imaging systems. At the completion of the course the student should have the ability to model signal and noise transfer within a multistage imaging system.

Course Objectives:
The student will be able to:

- Demonstrate a basic knowledge foundation that enables him/her to describe signals and noise in imaging systems.
- Apply a basic knowledge of noise and random processes to the optimization of S/N in imaging systems.

Topic Outline:

1. Probability
   (a) Set definitions and operations
   (b) Introduction to probability
   (c) Joint and conditional probability
   (d) Independent events
   (e) Combined experiments
   (f) Bernoulli trials

2. Random Variables
   (a) Random variable concept
   (b) Distribution function
   (c) Density function
   (d) Gaussian RV

   (e) Density and distribution examples
   (f) Conditional distribution and density functions

3. Operations on One RV — Expectation and Moments

   (a) Expectation
   (b) Moments
   (c) Functions that give moments
   (d) Transformations of a RV

4. Mutiple RVs

   (a) Vector RVs
   (b) Joint distribution and its properties
   (c) Joint density and its properties
   (d) Conditional distribution and density
   (e) Statistical independence
   (f) Distribution and density of a sum of RVs
   (g) Central limit theorem

5. Operations on Mutiple RVs

   (a) Expected value of a function of a RVs
   (b) Jointly Gaussian RVs
   (c) Sampling and some limit theorems

6. Random Processes — Temporal Characteristics

   (a) RP concept
   (b) Stationarity and independence
   (c) Correlation functions
   (d) Gaussian RPs
   (e) Poisson RPs

7. Random Processes — Spectral Characteristics

   (a) Power density spectrum and its properties
   (b) Relationship between power spectrum and autocorrelation function
   (c) Power spectrums for discrete-time processes and sequences
   (d) Cyclostationary RPs
   (e) White noise
   (f) Photon noise
   (g) Zero-frequency value of the NPS
   (h) Noise correlation
   (i) Zero-Frequency Analysis of Signal and Noise
   (j) Detective Quantum Efficiency
   (k) Approaches to defining the performance of detectors
   (l) DQE in Film Systems
   (m) DQE Examples

(n) DQE Transfer
(o) Photon Amplifier Modeling
(p) Cascaded DQE and Quantum Sinks
(q) Noise Equivalent Number of Quanta
(r) Photon Amplification

8. Fourier Analysis of Signal and Noise

   (a) Autocorrelation Function
   (b) Noise Power Spectrum
   (c) Detective Quantum Efficiency
   (d) Noise Equivalent Quanta
   (e) Noise Transfer
   (f) Noise Transfer — Granularity Transfer Example
   (g) Noise Transfer — Screen-Film System Example
   (h) Noise Transfer — General Treatment
   (i) Cascaded DQE
   (j) Radiographic Screen-Detector System
   (k) Quantum Accounting Diagram

9. Fourier Analysis of Signal and Noise in Digital Systems

   (a) Detector-element size and aperture MTF
   (b) Digital MTF: presampling and aliasing
   (c) Digital Wiener spectrum: presampling and noise aliasing
   (d) Digital DQE
   (e) Analysis of a digital detector array
   (f) System DQE

Instructional Techniques:

2.1 Textbook information is given below. The textbook will be supplemented with course notes in weeks 6- 10 which illustrate the applications in imaging science.

2.2 The lectures will focus on the main points of each chapter, often following the textbook or notes very closely. From the Course Schedule you can determine what topics will be covered in a particular week. You are expected to read that part of the course notes **prior** to coming to class so that you are prepared to discuss the material and ask questions. Lecture Slides are posted in the **Content** section of `myCourses`.

2.3 There are problem sets assigned from the problems at the end of each chapter in the textbook and these are posted in the **Content** section of `myCourses`. The problem sets will **not** be collected. Solutions are posted in the **Content** section of `myCourses`. Solutions to problems in Chpts 8-10 will be included in the course notes handout later in the quarter.

These problems give you an opportunity to apply probability theory and concepts. Use these problem sets to test your understanding of course material and to highlight areas needing further study. You can expect to see similar problems on the exams (see next section).

Learning Assessment:

3.1 The assessment of your degree of mastery of the course material and achievement of the course objectives is based on your performance on three exams — one during week 4 (Chpts 1 - 5), one during week 8 (Chpts 6 - 8), and a final exam during exam week. The final exam is comprehensive, but weighted toward the final two chapters (50% Chpts 1 - 8; 50% Chpts 9- 10). Each exam is worth 100 points, but points missed on the first two exams carry over to the final exam. For example, if you earned 50 points on exam # 1 and 75 points on exam # 2, you may earn up to 175 points on the final exam.

3.2 All exams are proctored, closed-book, problem-type exams consuming a maximum of one hour 50 minutes (two hours for the final exam). Each exam is designed to test your basic understanding of probability and random processes, and your ability to apply these tools in solving problems. Problems will be taken from the textbook body (including examples), as well as the assigned problems at the end of the chapters.

3.3 The final grade will be based on the total number of points earned in the three exams (300 points maximum). The conversion of the final numerical grade into a course letter grade is based on a curve.

Texts:

4.1 Required text: *Probability, Random Processes, and Random Signal Principles,* Peyton Z. Peebles, 4th Ed. McGraw-Hill, New York, 2001. Course notes for Chapters 8-10 will be handed out in week 5.

4.2 Reference texts: See individual chapters in textbook and course notes.

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