ENEE719P, Spring 2003, University of Maryland, College Park
Advanced Topics in Microelectronics: Sensory Information Processing VLSI Design

Instructor:
Dr. Pamela Abshire
2211 A. V. Williams Bldg.
pabshire@glue.umd.edu
(301) 405-6629
Office Hours: Tu 3:30-5:30pm (or by appt)

Class Time and Location: TuTh 2:00-3:15pm EGR 3106
(http://www.inform.umd.edu/CampusInfo/Facilities/Buildings/EGR/)

Course Description:
This course develops tools and techniques for studying information processing in natural sensory organs and in engineered sensory microsystems operating under physical constraints such as power limitations or performance requirements. Topics covered include: information theory; integrated microelectronic transducers, devices, and circuits; biological transducers, devices and circuits; noise theory in biological and electronic systems; modeling techniques for biological and electronic devices and systems; performance measures; energy cost of information processing; signal representations; and specific sensory applications such as vision and audition. Each student will complete a design project addressing an information processing problem in a specific sensory domain. Projects involving the design of integrated electronic circuitry can be submitted to MOSIS for fabrication. This course encourages multidisciplinary participation and will be offered to graduate students in both the Department of Electrical and Computer Engineering and the Neuroscience and Cognitive Science Graduate Program.

Course Website: www.ajconline.umd.edu

Course Outline:
I. Mathematical methods, physical origins, and characteristics
  a. Information theory:
    i. Introduction to the mathematical theory of communication
    ii. Optimal Communication (Rimoldi)
    iii. Energy per bit (Verdu)
  b. Thermodynamics of information processing:
    i. Maxwell's demon (Maxwell, Leff/Rex)
    ii. Second Law (Landauer)
    iii. Reversible Computation (Bennett)
    iv. Statistical Thermodynamics (Wyatt and Coram, Stratonovich)
    v. Fluctuation Dissipation Theorem (Callen/Welton)
  c. Noise mechanisms: fundamental and practical
    i. Microelectronics
    ii. Biology
  d. Transduction mechanisms:

i. Physics / biophysics
ii. Information Processing / Filtering
iii. Models (Miller, Johnston/Wu)

II. Visual information processing
  a. Light and information
  b. Sensory coding: Barlow/Atneave/Atick/Laughlin
  c. Spatial information capacity
  d. Neuromorphic engineering / synthetic sensory Microsystems
  e. Visual communication (Huck and Fales. Fales and Huck)

III. Tradeoffs in microelectronics:
  a. Sensory coding for filter banks (Furth and Andreou)
  b. Information-power tradeoffs for different signal representations, filter banks (Hosticka, Furth and Andreou)
  c. Sensory coding for imagers (Andreou)
  d. Information-power tradeoffs for photoreceptors and imagers (Abshire and Andreou)
  e. Information-power tradeoffs using linear models (Shanbhag, Abshire and Andreou)
  f. Information-power tradeoffs for simple linear systems (Abshire)

IV. Tradeoffs in Biology
  a. Blowfly photoreceptor as a communication network (I) - information processing level
  b. Blowfly photoreceptor as a communication network (II) - physical level
  c. Energy cost of information processing

V. Advanced Topics
  a. Information in Nonlinear systems: nonlinear dynamics, chaos, CMOS inverter, spikes
  b. Other Costs: design, fabrication, evolution, ontogeny
  c. Other Performance Measures
  d. Noise/Measurement in Quantum Systems

Texts:

No texts are required for this course. Course materials will be derived from journal articles and excerpts from books. These materials will be distributed during lectures, posted on the course website or available in hard copy outside the instructor's office, 2211 A. V. Williams. A cumulative bibliography for the course materials will be available on the course website.

Course Announcements:

In the beginning of the course, I will attempt to verify that class notifications are reaching your email address, however, it will be **your** responsibility to ensure continued reception of class information. All class announcements will be posted onto the class website as an alternative means of retrieving updated information.

Grading:

Your final grade will be based on class participation, assignments, presentations, and a final project. The following is a tentative weighting for determining overall grades.

Class Participation – 10%
Assignments (Takehome Midterm, Literature Review, Mini-project) – 30%
Class Presentations – 10%
Final Project – 50%

Absences:
While it is my intent to respect our diverse community's religious observances, it is the student's responsibility to inform me in writing (email) of any intended absences for religious observances in advance. Notice should be provided as soon as possible but no later than the end of the second week of classes.

Academic Integrity:
Academic dishonesty will not be tolerated. All work submitted for grading must be your own. In the case of group projects a summary should indicate the contributions of all members of the group. The University Code of Academic Integrity, which can be found at http://www.inform.umd.edu/CampusInfo/Departments/JPO/, prohibits students from committing the following acts of academic dishonesty: cheating, fabrication, facilitating academic dishonesty, and plagiarism. Instances of academic dishonesty will be referred to the Office of Judicial Programs.

Tentative Schedule (subject to change):

Wk	Date	Topic	References
1	Jan 28	Course overview; introduction to information theory	Shannon, Shannon and Weaver
1	Jan 30	Information Theory: Mathematical theory of communication	Shannon and Weaver, Cover and Thomas
2	Feb 4	Optimal Communication	Rimoldi, ElGamal
2	Feb 6	Capacity per unit cost	Verdu
3	Feb 11	Thermodynamics of information: Maxwell's demon, Second Law	Leff/Rex, Landauer
3	Feb 13	Reversible Computation, Statistical thermodynamics	Bennett, Wyatt and Coram, Stratonovich
4	Feb 18	Fluctuation Dissipation Theorem	Callen/Welton
4	Feb 20	Noise theory: fundamental and practical mechanisms	
5	Feb 25	Noise mechanisms: Microelectronics	Van der Ziel, Pavasovic
5	Feb 27	Noise mechanisms: Biology	De Felice
6	Mar 4	Transduction mechanisms: Physical Level Functional Level	Koch, Abshire and Andreou
6	Mar 6	Transduction mechanisms: Models	Manwani and Koch, Miller, Johnston/Wu
7	Mar 11	Information theory, sensory processing and	Richards

		visual communication	
7	Mar 13	Light and information	Jones, Bershad, Francia
8	Mar 18	Sensory coding	Barlow, Atneave, Laughlin
8	Mar 20	Sensory coding	Atick
9	Mar 25-27	Spring break	
10	Apr 1	Spatial information capacity	Snyder et al., Banks et al.
10	Apr 3	Neuromorphic Engineering / Synthetic Sensory Microsystems	Boahen and Andreou, Boahen
11	Apr 8	Visual communication	Fales and Huck , Huck and Fales
11	Apr 10	Tradeoffs in microelectronics: Sensory coding and Information-power tradeoffs for different signal representations, filter banks	Hosticka, Furth and Andreou
12	Apr 15	Sensory coding and Information-power tradeoffs for photoreceptors and imagers	Andreou, Abshire and Andreou
12	Apr 17	Information-power tradeoffs using linear models and for simple linear systems	Shanbhag, Abshire and Andreou, Abshire
13	Apr 22	Tradeoffs in Biology Blowfly photoreceptor as a communication network (I) - information processing	van Hateren
13	Apr 24	Blowfly photoreceptor as a communication network (II) - physical level	Abshire and Andreou
14	Apr 29	Energy cost of information processing	Laughlin et al.
14	May 1	Advanced Topics: Other Costs: design, fabrication, evolution, ontogeny	Williams et al., Gillooly et al.
15	May 6	Nonlinear systems: nonlinear dynamics / chaos / CMOS inverter	Abshire
15	May 8	Nonlinear systems: spikes	Goldberg et al.
16	May 13	Other Performance Measures Noise/Measurement in Quantum Systems	
	May 20	Final Project Presentations 10:30 am-12:30 pm	