BMNG5230 Biomedical signal analysis and modeling (full course description)

Justification:
This course is directed at the student interested in the analysis of physiological signals and modeling of physiological systems from the perspective of the biomedical engineer. There is currently no course offered at Dalhousie specifically focused on applying quantitative engineering analysis to biomedical signals, an important and significant area of research for Biomedical Engineering. This course is ideally paired with Biomedical instrumentation that in the spring term covers data acquisition and transducer instrumentation through programming in Labview. In this course, the focus will be on analysis of physiological signals using Engineering signal analysis approaches.

Instructors: Geoff Maksym, Kevin Deluzio, Andrew French, Milan Horacek.
Instructors will teach modules that best match their expertise.
Text: none
Prerequisites: Programming experience, differential equations and BMNG5210 Biomedical Instrumentation Data Acquisition and Analysis preferred.
Evaluation: 60% module assignments/40% project report.

Assignments accompany each module as described below.

The term project consists of either the construction of a physiological model or the analysis of acquired data using signal analysis and modeling approaches introduced in the class. Projects are to be conducted after the modules are completed, and will be carried out in the final 4 weeks of term. The project must be approved by the instructors based on a 1-2 paragraph proposal. An informal interim report will occur midway through the project. The project report will be in the form of scientific report prepared for peer-reviewed publication including, abstract, introduction, methods, results and discussion.

Course Outline:
The course will rely to a great extent on Matlab examples and Matlab programming for solution for the assignment problems. One to two class sessions will be used to introduce the Matlab programming language for the purposes of this course, and will be accompanied by a Matlab primer handout.

The course is organized in a series of modules as described below. The first 3 modules are core requirements for the course, and usually 3 more modules from the remaining 5 (numbers 4 through 8) will be covered based on the students background and interest. An assignment accompanies each module appropriate to the module topic. Where possible emphasis will be made on the similarities between analysis and modeling approaches. For example, in motion, vascular systems, respiratory mechanics, and reaction kinetics, electrical and mechanical equivalent circuits are often employed to describe the differential equations that govern these and many other physiological systems.

<u>Core Modules</u>
1) **Linear systems analysis:** Review of linear systems, and cover time domain and frequency domain analysis emphasizing dualities between approaches.
Examples/assignments: Human body motion from accelerometry/ time and frequency domain integration/differentiation.

2) **Linear systems modeling:** linear parametric modeling demonstrating development of impulse response functions and linear system transfer functions from 1st principles.
Examples/assignments: Electrophysiology, Cable equation volume conductor for modeling nerves.

3) **Linear System Identification:** Using synthetic and real data from physiological recordings, the process of identifying physiological relevant parameters from input/output data will be described.
Examples/assignments: a) Identification of the Respiratory system from broad-band pseudo-random noise input. B) Identification of neuromuscular EMG/Torque data (from here or Kearney in Montreal).

Additional Modules
4) **Orthogonal decomposition:** Modelling of biological system data using system specific orthogonal basis functions known as principal component analysis (rather than sinusoidal decomposition via Fourier).
Examples/assignments: Modeling gait waveform data.

5) **Biological Statistical Analysis and modeling.** Markov & non-Markov chains.
Examples/assignments: ion channel kinetics, membrane noise.

5) **Nonlinear system modeling:** Block structured modeling including Volterra series, Wiener and Hammerstein systems.
Examples/assignments: system identification of mechanoreceptor neuron firings

6) **Time-Frequency Analysis:** introduction to the Short Time Fourier Transform and Wavelet signal decomposition.
Examples/assignments: Analysis of bat or dolphin hunting signals, otoacoustic emissions (stimulated emission of sound from the inner ear cochlea).

7) Time-Series analysis of chaotic signals
This topic would include chaotic attractors, evolution of oscillatory systems to chaotic systems, detrended fluctuation analysis as applied to heart beat variation.
Examples/assignments: Assessment of physiological signal (heart beat, breath rate) for chaotic behavior.

Reference Materials:

1. Lecture materials: Instructor notes, handouts and assigned reference papers provided

2. Selected library texts:

Akay, Metin, Detection and estimation methods for biomedical signals, San Diego : Academic Press, c1996, QT 36 A313d 1996 199904 disk, DALWKK KELLOGG, 2 copies. 1 with disk.

Akay, Metin. Time frequency and wavelets in biomedical signal processing, Piscataway, NJ : IEEE Press, c1998, DALWKK KELLOGG, QT 26.5 T582 1998

Akay, Metin.Nonlinear biomedical signal processing, New York : IEEE Press, c2000-2001, v. 1. Fuzzy logic, neural networks, and new algorithms -- v. 2. Dynamic analysis and modeling. DALWKK KELLOGG, QT 26.5 N813 v.2:2001

Bendat, J.S. and A.G Piersol, Random Data: Analysis and Measurement Procedures (2nd edition), John Wiley and Sons, 1986, DALKIL DALSCI SCI & DALTEC TUNS: TA 340 B43 1986

Bendat, J.S. and A.G Piersol, Random Data: Analysis and Measurement Procedures (3rd edition), John Wiley and Sons, 1986, NSCCAV AV: TA 340 B43 2000.

Bronzino, Joseph D., 1937-, The biomedical engineering handbook, 2nd edition, 2000. DALTEC TUNS REF R 856.15 B56 2000 v.1 & R 856.15 B56 2000 v.2 &

This text is available on the web in PDF format to DAL users only at:
http://www.engnetbase.com/ejournals/books/book_summary/summary.asp?id=402

Bruce, Eugene N., Biomedical signal processing and signal modeling, New York : John Wiley, c2001. DALWKK KELLOGG, QT 26.5 B886b 2001

Marmarelis, P.Z. & V.A. Marmarelis, Analysis of Physiological Systems: The White Noise Approach, Plenum Press, 1978, (Not in library).

Oppenheim, Alan V, Schafer, Ronald W, Digital signal processing, Englewood Cliffs, N.J. : Prentice-Hall, c1975. DALKIL DALSCI SCI & DALTEC TUNS TK 5102.5 O245 1975, DALTEC TUNS

Peters, T. M. Williams, Jackie C., 1954- Bates, Jason H. T. The Fourier transform in biomedical engineering, Boston : Birkhäuser, c1998., DALWKK KELLOGG, QA 403.5 F775 1998

Shiavi, Richard., Introduction to applied statistical signal analysis. 2nd ed. San Diego : Academic Press, c1999., DALWKK KELLOGG, TK 5102.5 S555i 1999

Webster, John G. Medical Instrumentation, application and design 3rd edition, 1998 Wiley, NY. DALTEC TUNS, R 856 M42 1998

Webster, John G. The measurement, instrumentation, and sensors handbook. CRC Press published in cooperation with IEEE Press, c1999. ENGnetBASE http://www.engnetbase.com Access restricted: DAL users only.