HHNS 6200 Fall 2009
Research Methods in Biomechanics

This course was designed to expose students to advanced topics in biomechanics and instrumentation. These topics have been chosen to represent areas where an understanding is necessary for performing biomechanics research and reading biomechanics literature. Students will be presented with lecture material, will complete laboratory assignments, a midterm and final exam.

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Lecture Hours: Monday 9:00-11:50 AM ANNU 355

Laboratory (Bi-weekly) Tentatively scheduled Thursday 10 am to 1pm

Lecture Topics:

Bio-Instrumentation

- introduction to analog-to-digital recording
- introduction to biological transducers and signal conditioning
- electrical terminology
- examples of transducers
- critical instrumentation issues (input range, resolution, sampling rate, linearity etc)
- Nyquisit Theorem (aliasing error)

Numerical Methods in Biomechanics

- signal-to-noise ratio
- differentiation methods
- integration methods
- frequency domain processing
- Fourier Analysis (the frequency spectrum)
- frequency statistics applied to EMG (MnPF, MPF etc)
- Joint Time-Frequency Analysis
- smoothing techniques (analog and digital)
- moving average, polynomical fits, cubic splines
- filtering (bode plots, high and low-pass filters)
- analog (RC circuit) and digital methods (eg. Butterworth)
- auto and cross correlations
- spike triggered averaging

Electromyography and Muscle Mechanics

- force-length relationship
- force-velocity relationship
- force-EMG relationship
- factors affecting EMG including electrode spacing, conduction velocity, tissue filtering, etc
- indwelling EMG – sampling, filter issues

Analysis of Human Motion

- imaging techniques
- 2D analysis
- joint and segmental issues
- defining instantaneous joint centres
- rotation matrices
- 3D Analysis
- issues beyond 2D

Visual tracking device

- Eye tracking devices: pupil-sink versus pupil-reflection systems
- Calibration procedures for data acquisition of Eye angle or Point of Regard gaze data
- Theory behind calculation of the visual point of regard from pupil, corneal reflection position and scene image

Course Evaluation:

Assignments (2 x 10% each)	*20%*
Laboratory Reports (choice of 4 out of 5 x 10% each)	*40%*
Midterm Exam	*20%*
Final Exam	*20%*

Assignments: The assignments are intended to reinforce material presented in lecture and will require you to apply equations and processing methods discussed in class to supplied data sets, interpret processed data and finally writing about your findings in the context of literature. The written instructions for each assignment are included in the Lab Manual and you will receive a data CD with the data sets for each assignment in lecture.

Laboratory Reports**:** The laboratory reports are intended to reinforce material presented in lecture and provide hands-on experience with all aspects of bio-instrumentation, signal processing and data analysis. We will cover a different area of study for each of these five (5) laboratory seminar sessions. The laboratory experiences have been designed to encourage all biomechanics students to work together in laboratory to trouble shoot/complete the assigned lab with the goal of fostering a positive learning experience for all involved. Students enrolled in this course will be required to participate in all laboratory sessions and process the data collected. Following the lab, students will be asked to disseminate their findings in a formal laboratory report (e.g. Introduction, Methods, Results, Discussion). An outline describing the expectations and format for lab reports will be distributed in lecture.

Midterm and Final Exams: The midterm exam will cover material presented in lectures will test all material taught in the first half of the course (i.e. Signal Processing 1 & 2, Numerical Methods 1 & 2 and Bio Instrumentation 1 lectures; Assignment 1; Labs 1 and 2). The final exam will focus on remaining material (EMG 1 & 2; Kinematics 1 &2 and BioInsrumentation 2; Assignment 2; Labs 3 to 5) however, as the first part of the course contains important fundamental concepts, some overlap may be present.

To give you an idea of the expectations and potential examination questions, copies of exams from previous years will be made available to you prior to the mid-term and final examination.

Readings: Selected references and readings will be required for lectures. A list of required reading is attached. These reading will help in understanding the course material and it is advised that they are read prior to the assigned lecture. While the papers will not formally be taken up in class, you are responsible for their content.

Advice 👂
The assignments and laboratory seminar preparation can consume a very large amount of time depending on your background and how well you have synthesized the course material and supplementary readings. You should prepare for the laboratory sessions prior to arriving to collect the data. This will insure that the data you collect will address the lab questions and limit the number of times you have to recollect the data. Make sure to start the assignments and seminar preparation early, as there will be a new assignment or seminar almost every week. ☺
There will be no extensions and late material will receive a maximum of half marks.

Ethics

Ethical approval has been obtained from the Research Ethics Board at the University of Guelph for subject participation. Please refer to the University of Guelph ethics website for further information http://www.uoguelph.ca/research/humanParticipants/PDF/policies/1%20-%20Review%20Policies/1-G-008.pdf

If you have any concerns about the ethics of this research, please contact the University of Guelph ethics officer, Sandy Auld, Telephone: (519) 824-4120, ext. 56606, E-mail: sauld@uoguelph.ca, Fax: (519) 821-5236.

HK*6210 FALL 2009
COURSE OUTLINE

LECTURE TIMES: Monday 9 am - noon (ANNU 355)
LAB TIMES: Thursday 10 am to 1 pm
SEMINAR TIMES: Tuesday noon – 1pm

Week	Lecture Topic	Assignment/Lab
Sept 14 – 18 *(John)*	Signal Analysis 1 *(Properties of signals; time, amplitude domains)*	**Assignment 1**: *COP & COM calculations*
Sept 21 – 25 *(John)*	Signal Analysis 2 *(Frequency domain)*	***Lab 1:*** *A/D Conversion* *(Assignment 1 due)*
Sept 28 – Oct 2 *(John)*	Numerical Methods 1 *(Differentiation, integration smoothing, filters)*	*Lab 1 due*
Oct 5 – 9 *(Leah)*	Numerical Methods 2 *(Correlations; spike triggered avg) (Transducers)*	***Lab 2:*** *Frequency response: Analog & digital filters*
Oct 12 *(John)*	**Thanksgiving!** *Lecture moved to lab slot*	Lecture: Bioinstrumentation *(Transducers)* **Assignment 2:** *Fast Fourier Transforms* *Lab 2 due*
Oct 19 - 23		
Oct 26 - 30	Review *Assignment 2 due*	*Midterm Exam*
Nov 2 – 6 *(Leah)*	EMG 1 *(X-bridge theory; recruitment; instrumentation; velocity-force relationships)*	***Lab 3***: Surface and Indwelling EMG of FDI muscle
Nov 9 – 13 *(Leah)*	EMG 2 *(Force & fatigue relationship; EMG analysis techniques)*	*Lab 3 due*
Nov 16 – 20 *(Lori)*	Kinematics 1 *(Goinometer, electromagnetic, accelerometers, optical recordings; DLT theory)*	***Lab 4:*** *EMG: Frequency & amplitude domain (Note: data collected during FDI lab)*
Nov 23 – 27 *(Lori)*	Kinematics 2 *(Marker systems; reference frames; coordinate systems)*	***Lab 5:*** *Kinematics: Comparison of data from different marker systems* *Lab 4 due*
Nov 30 – Dec 4 *(Lori)*	Bio Instrumentation 2 (Anatomy of eye; visual pathways; gaze; scleral, EOG and video eye tracking systems)	*Lab 5 due*
Dec 7 - 11		Review Session

****Final Exam: Tentatively scheduled for Monday Dec 14, 2009 ****

Guidelines to Help Focus Reading of Scientific Papers

The following are some guidelines to keep in mind while reading scientific publications.

1. What was the reason for doing the work in the first place?
2. Was the question posed in a researchable way?
3. What was being measured?
4. Was the measure appropriate to answer #1?
5. How was it measured?
6. Was the measurement technique suitable?
7. Were there any assumptions or errors (implicit or explicit) that might nullify any conclusions drawn?
8. What were the main useful facts and findings?
9. What did the author(s) conclude?
10. Were the finding/data unequivocal? Were/are there other equally valid interpretations?
11. How would you have approached the research problem?

Suggested General Readings

1. W.G. Hopkins. Guidelines on Style for Scientific Writing. (available online at http://www.sportsci.org/jour/9901/wghstyle.html)

2. T. R. Lunsford and B. R. Lunsford. How to critically read a journal research article. *Journal of Prosthetics and Orthotics* 8 (1):24-31, 1996.

3. T. M. Wright, J. A. Buckwalter, and W. C. Hayes. Writing for the Journal of Orthopaedic Research. *J.Orthop.Res.* 17 (4):459-466, 1999.

Bio-instrumentation Section:

4. T.R. Derrick. Chapter 11: Signal Processing. In: Research Methods in Biomechanics, G.E. Robertson, G. Caldwell, J. Hamill, G. Kamen, S. Whittlesey. Human Kinetics Press, 2004.

5. Signal Conditioning and PC-Based Data Acquisition Handbook. Chapters 1, 2, & 5. Available online at http://www.iotech.com/prsigcon.html

6. The Scientist and Engineer's Guide to Digital Signal Processing. Chapter 3:ADC and DAC (specifically the sections on quantitization and sampling theorem) S.W. Smith. California Technical Publishing, San Diego, California, 1999. (available online through http://www.dspguide.com)

7. Strain Gauge Measurement – A Tutorial. National Instruments Application Note 078, 1998. (Available online through www.NI.com)

8. Introduction to Measurement Systems. In: Sensors and Signal Conditioning, Ramón Pallás-Areny and John G. Webster, Wiley-Interscience, New York, 1991, pg. 1-26.

9. Chapter 5:Things You Should Know about Analog Input, In: LabVIEW Data Acquisition Basics Manual, part of the LabVIEW manual set, pg. 5.1 – 5.17.

10. Inputs and Outputs. In: LabVIEW Graphical Programming – Practical Applications in Instrumentation and Control. Gary Johnson, McGraw-Hill:New York, 1994, pgs. 43-73.

11. Harry N. Norton. Biomedical Sensors : Fundamentals and Applications, Noyes Publications: Park Ridge, N.J., 1982 .

12. Measurement Techniques. In: Biomechanics of the Musculo-Skeletal System. B.M. Nigg and W. Herzog (eds.), Wiley: Chichester, 1994, pgs. 199-364.

Numerical Methods Section:

13. The Scientist and Engineer's Guide to Digital Signal Processing. S.W. Smith. California Technical Publishing, San Diego, California, 1999.
(available online through http://www.dspguide.com)

This is an informative and detailed text. The material is intended to reinforce the concepts that are covered in class. Accordingly, only certain sections are pertinent. For example,
Chapter 1: pages 1-3 DSP intro
Chapter 2: pseudocode representation of algorithms, Σ, time domain, pdf, cumulative pdf, precision/accuracy.
Chapter 3: quantitization and sampling theorem apply to Bioinstrumentation section.
Chapter 4: general concepts from pages 67-76.
Chapter 5: to page 100 & Fourier decomposition pg. 104.
Chapter 8:Discrete Fourier Transform
Chapter 14: Digital Filters etc.

14. Robertson D.G. and Caldwell G.E. Differentiation within Chapter 1:Planar Kinematics, In: Research Methods in Biomechanics, G.E. Robertson, G. Caldwell, J. Hamill, G. Kamen, S. Whittlesey. Human Kinetics Press, 2004.

15. R. Block. Subtraction of electrocardiographic signal from respiratory electromyogram. *J Appl Physiol* 55:619-623, 1983.

16. P. Dolan, A. F. Mannion, and M. A. Adams. Fatigue of the erector spinae muscles: A quantitative assessment using "frequency banding" of the surface electromyography signal. *Spine* 20 (2):149-159, 1995.

17. D. Hary, M. J. Belman, J. Propst, and S. Lewis. A statistical analysis of the spectral moments used in EMG tests of endurance. *J Appl Physiol* 53:779-783, 1982.

18. R. S. Person and L. N. Mishin. Auto and cross-correlation analysis of the electrical activity of muscles. *Med & Biol Engng* 2:155-159, 1964.

19. J. Pezzack, R. W. Norman, and D. A. Winter. An assessment of derivative determining techniques used for motion analysis. *J Biomechanics* 10:377-382, 1977.

20. G. Smith. Padding point extrapolation techniques for the butterworth digital filter. *J Biomechanics* 22:967-971, 1989.

21. D.G.E. Robertson, J.J. Dowling. Design and responses of Butterworth and critically damped digital filters. *J Electromyogr.Kinesiol.* 13:569–573, 2003

22. G. A. Wood and L. S. Jennings. On the use of spline functions for data smoothing. *J Biomechanics* 12:477-479, 1979.

Electromyography Section

23. G. Kamen. Chapter 6: Electromyographic Kinesiology , In: Research Methods in Biomechanics, G.E. Robertson, G. Caldwell, J. Hamill, G. Kamen, S. Whittlesey. Human Kinetics Press, 2004.

24. JR Potvin. Effects of muscle kinematics on surface EMG amplitude and frequency during fatiguing dynamic contractions. *J Appl Physiol*. 82(1):144-51, 1997.

25. J. Yang and D. A. Winter. Electromyographic amplitude normalization methods: Improving their sensitivity as diagnostic tools in gait analysis. *Arch Phys Med Rehabil* 65:517-521, 1984.

26. G. L. Soderberg and T. M. Cook. Electromyography in biomechanics. *Physical Therapy* 64:1813-1820, 1984.

27. G. L. Soderberg (editor). *Selected topics in surface electromyography for use in the Occupational Setting: Expert perspectives*. US Department of Health and Human Services. Public Health Service. Centers for Disease Control - National Institute for Occupational Safety and Health (NIOSH).1992.

28. B Gerdle, NE Eriksson, L Brundin. The behaviour of the mean power frequency of the surface electromyogram in biceps brachii with increasing force and during fatigue. With special regard to the electrode distance. Electromyogr Clin Neurophysiol. 30(8):483-9, 1990.

29. RM Enoka, LL Rankin, DG Stuart, KA Volz. Fatigability of rat hindlimb muscle: associations between electromyogram and force during a fatigue test. J Physiol. 408:251-70. 1989

30. Y Umezu, T Kawazu, R Tajima, H Ogata. Spectral electromyographic fatigue analysis of back muscles in healthy adult women compared with men. Arch Phys Med Rehabil. 79(5):536-8. 1998

31. S. E. Mathiassen and J. Winkel. Quantifying variation in physical load using exposure-vs-time data. *Ergonomics* 34 (12):1455-1468, 1991.

32. Fuglevand A. Neural aspects of fatigue. *The Neuroscientist*. Vol 2(4). 203-206. 1996

33. Measurement Techniques: EMG. In: Biomechanics of the Musculo-Skeletal System. B.M. Nigg and W. Herzog (eds.), Wiley: Chichester, pgs. 308-334. 1994

34. T Moritani, A Nagata, M Muro. Electromyographic manifestations of muscular fatigue. *Med Sci Sports Exerc*. 14(3):198-202. 1982

Analysis of Motion Section:

35. D.G.E. Robertson and G.E. Caldwell. Chapter 1: Planar Kinematics. In: Research Methods in Biomechanics, G.E. Robertson, G. Caldwell, J. Hamill, G. Kamen, S. Whittlesey. Human Kinetics Press, 2004.

36. J Hamill and W.S. Selbie. Chapter 2: Three-Dimensional Kinematics. In: Research Methods in Biomechanics, G.E. Robertson, G. Caldwell, J. Hamill, G. Kamen, S. Whittlesey. Human Kinetics Press, 2004.

37. Measurement Techniques: Optical Methods. In: Biomechanics of the Musculo-Skeletal System. B.M. Nigg and W. Herzog (eds.), Wiley: Chichester, pgs. 254-286. 1994.

38. Cappozzo, A. Three-dimensional analysis of human walking: Experimental methods and associated artifacts. Human Movement Science. 10:589-602, 1991.

39. ES Grood, WJ Suntay. A Joint coordinate system for the clinical description of the three dimensional motions: Applications to the knee. J. Biomech Eng 105(2): 136-144. 1983.

40. Wu G, van der Helm FC, Veeger HE, Makhsous M, Van Roy P, Anglin C, Nagels J, Karduna AR, McQuade K, Wang X, Werner FW, Buchholz B; International Society of Biomechanics. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion--Part II: shoulder, elbow, wrist and hand.J Biomech. 2005;38(5):981-992.

41. S. H. Wei, K. J. McQuade, and G. L. Smidt. Three-Dimensional Joint Range of Motion Measurements from Skeletal Coordinate Data. *Journal of Orthopaedic and Sports Physical Therapy* 18 (6):687-691, 1993. [description and sample calculation of Euler Angles]

42. N. Bogduk, B. Amevo, and M. Pearcy. A biological basis for instantaneous centres of rotation of the vertebral column. *Proc.Inst.Mech.Eng [H.]* 209 (3):177-183, 1995.

43. H Mannel, F Marin, L Claes, L Durselen. Establishment of a knee-joint coordinate system from helical axes analysis--a kinematic approach without anatomical referencing. *IEEE Trans Biomed Eng*. 51(8):1341-7. 2004

44. TS Johnson, TP Andriacchi, AG Erdman. Sensitivity of finite helical axis parameters to temporally varying realistic motion utilizing an idealized knee model. *Proc Inst Mech Eng*; 218(2):89-100. 2004

Eye Tracking Systems Section:

45. Allum Honegger and Troescher. Principles underlying real-time nystagmus analysis of horizontal and vertical eye movements recorded with electro-infrared, or Video occulographic techniques. Journal of Vestibular Research 8(6): 449-463. 1998

46. DiScenna, Das Zivotofsky, Seidman and Leigh. Evaluation of a video tracking device for measurement of horizontal and vertical eye rotations during locomotion. Journal of Neuroscience Methods. 58:89-94. 1995.

47. Kim, Nam, Sang Lee and Won Kim. A new method for accurate and fast measurement of 3D eye movements. Medical Engineering & Physics. 28: 82-89. 2006.

48. Schmitt, Muser, Lanz, Walz and Schwarz. Comparing eye movements recorded by search coil and eye tracking. Journal of Clinical Monitoring and Computing 21: 49-53. 2007

49. Brown, Marmor, Vaegan, Zrenner, Brigell, Bach. ISCEV Standard for Clinical Electro-oculography (EOG). Doc Ophthalmol 113: 205-212. 2006

50. Barea, Boquete, Mazo and Lopez. System for assisted mobility using eye movements based on electrooculography. IEEE Transactions on neural Systems and Rehabiitation Engineering 10 (4): 209-218. 2002

51. Imai, Sekine, Hattori, Takeda, Koizuka, Nokamae, Miura, Fujioka and Kubo. Comparing the accuracy of video-oculography and the scleral search coil system in human eye movement analysis. Auris Nasus Larynx. 32: 3-9. 2005