HBNS 6210 Fall 2010
Exploring Research Techniques in Biomechanics

The primary objective of this course is to expose students to advanced topics in biomechanics and instrumentation. Topics have been chosen to represent areas where an understanding is necessary for performing biomechanics research and reading biomechanics literature. Students will gain an increased ability to critically evaluate related literature and will also become familiarized, through hands-on laboratory sessions using state-of-the-art equipment, with practical laboratory skills (data acquisition, trouble shooting). To achieve this objective, particular attention will be given to the provision of a fundamental background in biomechanics instrumentation which will provide students will knowledge in diverse, but related areas of study that include, anatomy, muscle physiology, engineering, electronics and physics principles.

At the conclusion of this course, students should be able to:

- apply theoretical knowledge to the execution of practical laboratory skills, i.e. use appropriate techniques to convert analog electronic signals to digital electronic signals
- reduce signal to noise relationships in electronic signals (i.e. know when and how to apply different filtering and/or smoothing techniques)
- characterize force relationships from electromyographic data based on theoretical knowledge of muscle mechanics and neural control of muscle recruitment
- compare and contrast different kinematic measurement systems and determine the optimal system for specific biomechanics research questions
- outline the steps required to calculate 3D kinematic motion from 2D data acquired through video based kinematic measurement systems and determine the best approach for relaying 3D linear and rotational motion of the body to answer specific research questions in the field (i.e. use of Euler angle versus Joint Coordinate system to relay degree of human motion)
- compare and contrast different visual tracking systems and determine which system is optimal for specific biomechanics research questions

Students will be presented with lecture material, will participate in hands-on laboratory sessions and present findings from these experiences in an oral seminar to their peers. Students will also be required to complete a take home final examination.

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Lecture Hours:	Friday 9:00 -11:50AM	(Science Complex 3310)
Laboratory (weekly):	Monday 9:00 – 11:50AM	(JTP 208B)
Seminars (weekly):	Wednesday Noon to 1PM	()

<u>Lecture Topics:</u>
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%*
Oral Laboratory Seminars (5 x 10% each)	*50%*
Take Home Final Exam	*30%*

Late penalty: 10% per day late up to 5 days; if an assignment is late due to medical or personal reasons, documentation is required at the digression of the instructor.

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.

Oral Laboratory Seminars**:** The seminar series is 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 a portion of the data collected. Following the lab, students will be asked to orally present specific findings from their portion of the lab experience to the entire biomechanics group, in a "Journal Club" type format, and discuss these findings in the context of assigned readings from the literature. An outline describing the format for seminar preparation, oral delivery in a given topic area, delivery and expectations will be distributed in lecture.

Take Home Final Exam: This exam will test all material taught in the course, i.e. it will be a cumulative exam, and students will have ~ 48 hours to complete the exam. This format will allow flexibility for how you chose to tackle this final evaluation component however page limitations for each question will be strictly enforced. *To give you an idea of the expectations and potential examination questions, copies of final exams from previous years will be made available to you prior to 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 2010
COURSE OUTLINE

LECTURE TIMES: Friday 9 am - noon (Science Complex 3310)
LAB TIMES: Monday 9 am to noon (JTP 208B)
JOURNAL CLUB: Wednesday Noon – 1pm (ANNU??)

Date	Lecture Topic (Fri)	Date	Assignment/Lab (Mon)
Sept 10 *(Dan)*	Overview of Course Signal Analysis *(Properties of signals; time, amplitude domains; Frequency domain)*	Sept 13 *(Lori)*	**Assignment 1**: ***(Lori)*** *COP & COM calculations*
Sept 17 *(John)*	Numerical Methods 1 *(Differentiation, integration smoothing, filters)*	Sept 20 *(Dan)*	***Lab 1:*** *A/D Conversion & Frequency response: Analog & digital filter*
Sept 24 *(John)*	Bioinstrumentation *(Transducers)* *(Assignment 1 due)*	Sept 27 *(John & Dan)*	***Lab 2:*** *Using an oscilloscope & DAQ to acquire data from Transducer (spring damper system)* *Lab 1 presentation Sept 29*
Oct 1 *(Dan)*	Programming *(Programming in Labview: .ni's and .vi's)*	Oct 4 *(John)*	**Assignment 2:** *LabView: Introduction to Coding (filtering, differentiation, interpolation, resampling, extrapolation)* *Lab 2 presentation Oct 6*
Oct 8 *(Leah)*	Numerical Methods 2 *(Correlations; spike triggered avg)* *(Transducers)*	Oct 11	*Thanksgiving Holiday*
Oct 15	Review Session *Assignment 2 due*	Oct 18	
Oct 22 *(Leah)*	EMG 1 *(X-bridge theory; recruitment; instrumentation; vel-force relationships)*	Oct 25 *(Leah)*	***Lab 3***: Surface & Indwelling EMG of FDI muscle
Oct 29 *(Leah)*	EMG 2 *(Force & fatigue relationship; EMG analysis techniques)*	Nov 1 *(Leah)*	***Lab 4:*** *EMG: Frequency & amplitude domain (Note: data collected during FDI lab)* *Lab 3 presentation Nov 3*
Nov 5 *(Lori)*	Kinematics 1 *(Goinometer, electromagnetic, accelerometers, optical recordings; DLT theory)*	Nov 8 *(Lori)*	***Lab 5:*** *Kinematics: Comparison of data from different marker systems* *Lab 4 presentation Nov 10*
Nov 12 *(Lori)*	Kinematics 2 *(Marker systems; reference frames; coordinate systems)*	Nov 15	*Lab 5 presentation Nov 17*
Nov 19 *(Lori)*	Bio Instrumentation 2 (Anatomy of eye; visual pathways; gaze; scleral, EOG & video eye track systems)	Nov 22 *(All)*	***Overview Lab?*** *NO written report*
Nov 26	Review Session	Nov 29	

****Final Exam Period is Dec 6-17; Exam is Tentatively scheduled for Monday Dec 6, 2010**

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