

# Smart Lab Coat for the Dental Practitioner

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# Overview of Presentation

- Motivation
- Background – Ergonomics
- Background – Computer Science
- Prototype
- Early Data and Analysis
- Future Work

# Motivation

- Needs of the VCU School of Dentistry
  - DentSim and Technology in VCU School of Dentistry
  - Current training given in conjunction with cavity preparation training
  - Instructor availability
  - Student perceptions



DentSim Simulator

# Background - Ergonomics

- Ergonomics and Dentistry
  - Work-related musculoskeletal disorders (WMSDs)
  - Causes of WMSDs in dentistry
    - Prolonged static postures
  - Costs of WMSDs
    - Medical costs and lost work
  - Changes in dentistry to alleviate WMSDs
    - Four-handed and seated dentistry
    - Chair design and layout of workspace

# Ergonomics in Dentistry

- Ways to correct posture:
  - Holistic approach
    - Stretching
    - Taking breaks
    - Adjusting chair and patient's chair
    - Core strength training
  - PAI System
  - Loupes
  - Dental chair design
  - Workspace environment



Posture Assessment Instrument

# Background - Ergonomics

- Traditional Ergonomics Methods:
  - Qualitative approaches
    - Observation
    - Surveys and Questionnaires
  - Quantitative approaches
    - Goniometers and image analysis
    - EMG recordings



Goniometer

# Background - Engineering

- Motivations for measuring human movement
  - Ergonomics / Posture
  - Gait Analysis / Medical Applications
  - Sports Analysis
  - Animation
- Methods of recording motion:
  - EMG
  - Video and Image Analysis
  - Motion Capture
  - On Body Sensors

# Background - Measuring Human Movement

1. Data Collection
2. Data Filtering
3. Data Analysis
4. Feedback to user(s)



# Background - Data Collection: Sensors

- On Body Sensors
  - Accelerometers / Inclinometers
  - Gyroscopes
  - Pressure Sensors
  - “Smart” Fabric
  - Magnetometers
  - Potentiometers



SCAT121T Series 2-Axis Inclinometer

# Background - Filtering of Data

- Two Motivations:
  - Feature extraction
  - Noise reduction
- Methods of Filtering:
  - Fourier Transformation
  - Discrete Wavelet Transformation and Wavelet Packet Decomposition
  - Complementary Quaternion Filters
  - Discrete-time complementary Kalman filters
  - Combination of methods above

# Background - Data Analysis

- Classification of movement based on extracted features:
  - Statistical Methods
  - Neural networks
    - Clustering algorithms
  - Combinations of existing machine learning techniques

# Background - User Interfaces

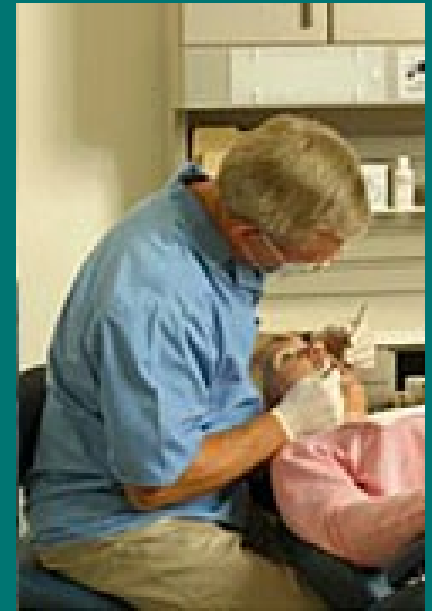
- Real time vs. non-real time systems
- Feedback to user vs. feedback to experts
- Feedback to correct movement or position vs. feedback to be further analysed by experts or other systems
- Feedback to system localized on user vs. feedback to a centralized source

# Posture Measuring Prototype

- A system to measure and classify posture
  - Accurate
  - Non-invasive
  - Inexpensive
  - Customized for each user
  - Unobtrusive
  - Real-time classification and feedback



Good Posture

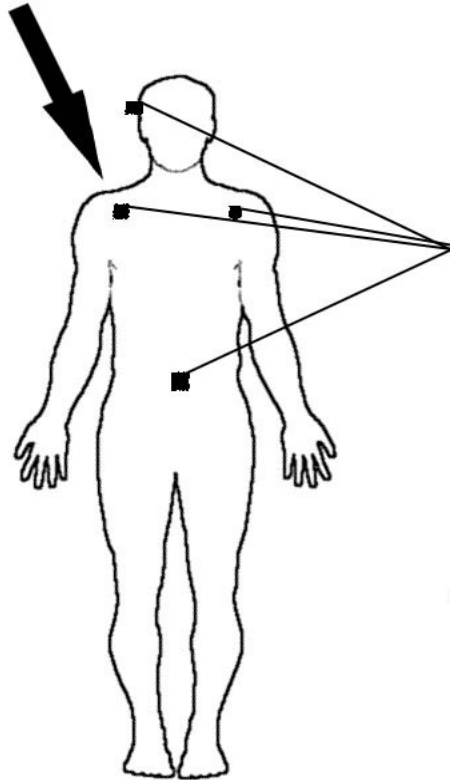


Poor Posture

# Posture Measuring Prototype

- Hardware:
  - Multiple Inclinometer Sensors
  - Analog to Digital Converter
  - Pocket PC(?)
  - User Interface

*Strategically placed  
inclinometers (sewn into  
a laboratory coat)*



*Analog-to-digital converter  
on a circuit board,  
connected to both the  
inclinometers and the  
Pocket PC (will also be  
attached to lab coat)*



*Headphones  
connected to  
Pocket PC for  
audio user  
interface*



*Pocket PC (connected to  
circuit board via serial  
cable) with software to  
filter and classify posture,  
and notify user if posture  
is harmful. Will reside in  
pocket of the lab coat.*

# Posture Measuring Prototype

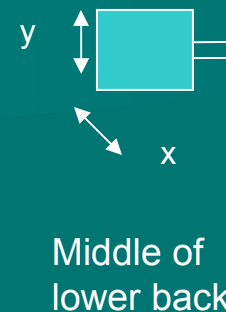
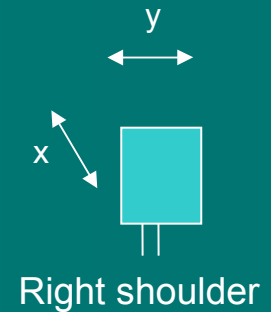
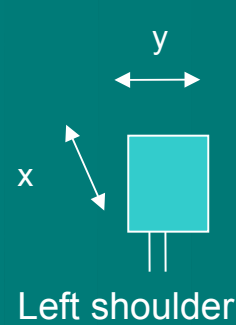
## ■ Software:

- Interpreting changes in incline from inclinometers
- Calibration
- Filtering
- Classification
- Notification / User Interface



# Initial Data Collection

- Data collected in one to three minute time intervals (approx. 1 reading per second)
- Five different positions recorded: nominally “good”, leaning left, leaning right, leaning forward, leaning back, slouching
- Trained on an ANN



# Initial Data – Trial 1

	Back X	Back Y	R. Shoulder X	R. Shoulder Y	L. Shoulder X	L. Shoulder Y
“Correct” Position – Actual Data	1.171°	55.256°	52.583°	35.972°	68.528°	-2.354°
Difference from “Correct” Position:						
Leaning Forward	+0.659°	+2.894°	+14.980°	-1.875°	+18.299°	-7.950°
Leaning Left	+4.271°	-1.353°	+5.487°	+9.972°	+15.000°	-16.309°
Leaning Right	-8.929°	-4.388°	+18.465°	-17.434°	+20.988°	+12.169°
Slouching	-4.327°	-10.114°	+13.592°	-6.641°	+17.362°	-1.012°
Leaning Back	-3.089°	-8.110°	-1.109°	+0.119°	-1.493°	+4.436°

# Initial Data – Trial 2

	Back X	Back Y	R. Shoulder X	R. Shoulder Y	L. Shoulder X	L. Shoulder Y
“Correct” Position – Actual Data	5.081°	57.987°	45.784°	33.318°	51.881°	0.974°
Difference from “Correct” Position:						
Leaning Forward	+2.068°	+9.426°	+17.502°	+4.636°	+20.702°	-8.663°
Leaning Left	+6.165°	+1.994°	-0.146°	+16.022°	+7.603°	-14.928°
Leaning Right	-14.227°	+6.284°	+19.181°	-18.589°	+18.775°	+18.208°
Slouching	-5.607°	-6.282°	+11.204°	+2.066°	+14.711°	-3.992°
Leaning Back	-6.628°	-2.053°	-13.858°	+4.577°	-11.799°	+6.807°

# Initial Data – Trial 3

	Back X	Back Y	R. Shoulder X	R. Shoulder Y	L. Shoulder X	L. Shoulder Y
“Correct” Position – Actual Data	-11.05°	19.19°	34.31°	-11.7°	32.33°	-7.06°
Difference from “Correct” Position:						
Leaning Forward	-3.23°	+6.15°	+13.76°	+3.31°	+15.97°	-2.93°
Leaning Left	+9.99°	+4.16°	+7.89°	-15.14°	+8.84°	-17.22°
Leaning Right	-14.25°	+2.84°	+12.07°	+25.29°	+10.97°	+26.4°
Slouching	-1.16°	-8.42°	+5.67°	+3.89°	+6.65°	+0.77°
Leaning Back	+1.28°	-1.69°	-2.55°	+1.21°	-4.74°	+4.75°

# Initial Analysis

## ■ Initial Results:

- 77% of trained data classified correctly as “good”, 64% of test data classified correctly as “good”
- No false positives except leaning forward
  - 88% of all leaning forward test data was classified as “good”
- 99.8% of all other “poor” postures correctly identified as “poor”
- Data from another session has mixed accuracy

# Future Work

- Portability – Pocket PC
- Filtering
- Analysis
- Real time testing of system
- User interface design
- Testing on dental students

Questions?

# References

- Valachi B, Valachi K. "Mechanisms leading to musculoskeletal disorders in dentistry" in Journal of the American Dental Association, vol. 135 no. 10, 1344-50, 2003.
- Thornton LJ, Stuart-Buttle C, Wyszynski TC, and Wilson ER. "Physical and psychosocial stress exposures in US dental schools: the need for expanded ergonomics training" in Applied Ergonomics, vol. 35 no. 2, 153-7, 2003.
- Simmer-Beck, M. and Branson, B. "Posture Perfect" in Dimensions of Dental Hygiene, vol. 3, no. 14, 2005.
- "National Occupational Research Agenda for Musculoskeletal Disorders." National Institute for Occupational Safety and Health. 01 Jan. 2001. U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES. 3 July 2007 <<http://www.cdc.gov/niosh/pdfs/2001-117.pdf>>.
- Buchanan, Judith, "Experience with Virtual Reality-Based Technology in Teaching Restorative Dental Procedures" in Journal of Dental Education, vol. 86, no. 12, 1258-1265, 2004.
- Valachi, B., Valachi, K. "Preventing musculoskeletal disorders in clinical dentistry" in Journal of the American Dental Association, vol. 134, 1604-1612, 2003.
- Finsen L, Christensen H, Bakke M. "Musculoskeletal disorders among dentists and variation in dental work" in Applied Ergonomics, vol. 29, no. 2, 119-25, 1998.
- Branson BG, Williams KB, Bray KK, McInay SL, Dickey D. "Validity and Reliability of a Dental Operator Posture Assessment Instrument (PAI)" in Journal of Dental Hygiene, vol. 76, no. 4, 255-61, 2002.
- Liss, G. M., Jesin, E., Kusiak, R. A., White, P. "Musculoskeletal Problems Among Ontario Dental Hygienists" in American Journal of Industrial Medicine, vol. 28, 521-540, 1995.
- Dougherty, M. "Ergonomic principles in the dental setting: Part 1" in Dental Products Report, 2001.
- Bishop, C. M. Neural Networks for Pattern Recognition. Oxford U.K.: Oxford University Press, 1995.
- Ripley B.D. Pattern Recognition and Neural Networks Cambridge U.K.: Cambridge University Press, 1996.
- Plamondon, A., Delise, A., Larue, C., Brouillette, D., McFadden, D., Desjardins, P., Lariviere, C. "Evaluation of a hybrid system for three-dimensional measurement of trunk posture in motion." In Applied Ergonomics, vol 38, 697-712, 2007.
- Gallagher, A., Matsuoka, Y., Ang, W. "An Efficient Real-Time Human Posture Tracking Algorithm Using Low-Cost Inertial and Magnetic Sensors." in IEEE/RSJ International Conference on Intelligent Robots and Systems, Proceedings, vol. 3, 2967 – 2972, 2004.
- Mantjarvi, J., Himberg, J., Seppanen, T. "Recognizing Human Motion with Multiple Acceleration Sensors." in 2001 IEEE International Conference on Systems, Man, and Cybernetics, vol. 2, 747 – 752, 2001.
- Lou, E., Bazzarelli, M., Hill, D., Durdle, N. "A Low Power Accelerometer Used to Improve Posture" in Canadian Conference on Electrical and Computer Engineering, vol. 2, 1385 – 1389, 2001.
- Bouten, C., Sauren, A., Verduin, M., Janessen, J. "Effects of placement and orientation of body-fixed accelerometers on the assessment of energy expenditure during walking." in Medical and Biological Engineering and Computing, vol. 35, 50-56, 1997.
- Minnen, D., Starner, T., Ward, J.A., Lukowicz, P., Troster, G. "Recognizing and Discovering Human Actions from On-Body Sensor Data." IEEE Conference on Multimedia and Expo, 1545-1548. 2005.
- Luinge, H. J. and Veltink, P. H. "Inclination Measurement of Human Movement Using a 3-D Accelerometer with Autocalibration." in IEEE Transactions on Biomedical Engineering, vol. 53, 1385-1393. 2006.
- Huynh, T. and Schiele, B. "Analyzing Features for Activity Recognition." in Proceedings of the 2005 Joint Conference on Smart Objects and Ambient intelligence: innovative Context-Aware Services: Usages and Technologies, vol. 121, 159-163. 2005.



# References

- Allen, F., Ambikairajah, E., Lovell N., Celler, B. "Classification of a known sequence of motions and postures from accelerometry data using adapted Gaussian mixture models." in *Physiological Measurement*, vol. 27, 935-951, 2006.
- Vehkaoja, A., Zakrzewski, M., Lekkala, J., Iyengar, S., Bajcsy, R., Glaser, S., Sastry, S., and Jafari, R. "A Resource Optimized Physical Movement Monitoring Scheme for Environmental and on-Body Sensor Networks." in *Proceedings of the 1st ACM SIGMOBILE international Workshop on Systems and Networking Support For Healthcare and Assisted Living Environments*, 64-66. 2007.
- Zhu, R., and Zhou, Z. "A Real-Time Articulated Human Motion Tracking Using Tri-Axis Inertial/Magnetic Sensors Package." in *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 12, 295-302, 2004.
- Young, A.D., Ling, M.J., Arvind, D.K. "Orient-2: A Realtime Wireless Posture Tracking System Using Local Orientation Estimation." in *Proceedings of the 4th workshop on Embedded networked sensors*, 53-57, 2007.
- Bazzarelli, M., Durdle, N., Lou, E., Raso, J. "A Low Power Portable Electromagnetic Posture Monitoring System." in *IEEE Instrumentation and Measurement*, 619-623, 2001.
- Wong, W.Y., Wong, M.S, Lo, K.H. "Clinical applications of sensors for human posture and movement analysis." in *Prosthetics and Orthotics International*, vol. 31, 62-75, 2007.
- Engin, M., Demirag, S., Engin, E., Celbi, G., Ersan, F., Asena, E., Colakoglu, Z. "The classification of human tremor signals using artificial neural network." in *Expert Systems with Applications*, vol. 33, 754-761, 2007.
- Lanningham-Foster, L., Jensen, T., McCrady, S., Nysse, L., Foster, R. Levine, J. "Laboratory Measurement of Posture Allocation and Physical Activity in Children." in *Medicine and Science in Sports and Exercise*, vol. 37, 1800-1805, 2005.
- Foerster, F. Smeja, M., Fahrenberg, J. "Detection of posture and motion by accelerometry: a validation study in ambulatory monitoring." in *Computers in Human Behavior*, vol. 15, 571-583, 1999.
- Fahrenberg, J., Foerster, F., Smeja, M., Muller, W. "Assessment of posture and motion by multichannel piezoresistive accelerometer recordings." in *Psychophysiology*, vol. 34, 607-612, 1997.
- Iso, T. and Yamazaki, K. "Gait Analyzer based on a Cell Phone with a Single Three-axis Accelerometer." in *Proceedings of the 8th conference on Human-computer interaction with mobile devices and services*, vol. 159, 141-144, 2006.
- Lee, R., Laprade, J., Fung, E. "A real-time gyroscopic system for three-dimensional measurement of lumbar spine motion." in *Medical Engineering and Physics*, vol. 25, 817-824. 2003.
- Mathie, M.J., Basilakis, J., Celler, B.G. "A System for Monitoring Posture and Physical Activity Using Accelerometers." in *Proceedings of the 23rd Annual EMBS International Conference*, 3654-3657. 2001.
- Nevins, R. Durdle, N., Raso, V. "A Posture Monitoring System Using Accelerometers." in *Proceedings of the 2002 IEEE Canadian Conference on Electrical and Computer Engineering*, 1087-1092. 2002.
- Lyons, G.M., Culhane, K.M., Hilton, D., Grace, P.A. Lyons, D. "A description of an accelerometer-based mobility monitoring technique." in *Medical Engineering and Physics*, vol. 27, 497-504. 2005.
- Burchfield T.R. And Venktesan, S. "Accelerometer-Based Human Abnormal Movement Detection in Wireless Sensor Networks." in *Proceedings of the 1st ACM SIGMOBILE international workshop on Systems and networking support for healthcare and assisted living environments*, 67-69. 2007.

# References

- Lee, R.Y.W. "Kinematics of rational mobilisation of the lumbar spine." in *Clinical Biomechanics*, vol. 16, 481-488. 2001.
- Bull, A.M.J. And McGregor, A.H. "Measuring spinal motion in rowers: the user of an electromagnetic device." in *Clinical Biomechanics*, vol. 15, 772-776. 2000.
- Tong, K. and Granat, M. H. "A practical gait analysis system using gyroscopes." in *Medical Engineering and Physics*, vol. 21, 87-94. 1999.
- Motoi, K., Tanaka, S., Nogawa, M., Yamakoshi, K. "Evaluation of a new sensor system for ambulatory monitoring of human posture and walking speed using accelerometers and gyroscope." in *SICE Annual Conference in Fukui*, 1232-1235. 2003.
- Lorussi, F. Schilingo, E.P., Tesconi, M. Tognetti, A. De Rossi, D. "Wearable Sensing Garment for Posture Detection, Rehabilitation and Tele-Medicine." in *Proceedings of the 4th Annual IEEE Conference on Information Technology Applications in Biomedicine*, 287-290. 2003.
- Whitman, L., Jorgensen, M., Hathiyari, K., Malzahn, D. "Virtual Reality: Its Usefulness for Ergonomic Analysis." in *Proceedings of the 2004 Winter Simulation Conference*, vol. 2, 1740-1745. 2004.
- Mutlu, B., Krause, A., Forlizzi, J., Guestrin, C., Hodgins, J. "Robust, Low-cost, Non-intrusive Sensing and Recognition of Seated Postures." in *Proceedings of the 20th annual ACM symposium on User interface software and technology*, 149-158. 2007.
- Omlor, L. and Giese, M.A. "Extraction of spatio-temporal primitives of emotional body expressions." in *Neurocomputing*, vol. 70, 1938-1942. 2007.
- Mayagoitia, R.E., Nene, A.V., Veltink, P.E. "Accelerometer and rate gyroscope measurement of kinematics: an inexpensive alternative to optical motion analysis systems." in *Journal of Biomechanics*, vol. 35, 537-542. 2002.
- Bonato, P. "Wearable Sensors/Systems and Their Impact of Biomedical Engineering." in *IEEE Engineering in Medicine and Biology Magazine*, vol. 22, 3, 18-20. 2003.
- DeRossi, D., Lorussi, F., Mazzoldi, A., Scilingo, E.P. "Active Dressware: Wearable Proprioceptive Systems Based on Electroactive Polymers." in *The Fifth International Symposium on Wearable Computers*, 161-162. 2001.
- DeRossi, D., Lorussi, F., Mazzoldi, A., Orsini, P., Scilingo, E.P. "Monitoring Body Kinematics and Gesture Trought Sensing Fabrics" in *1st Annual International IEEE-EMDS Special Topic Conference on Microtechnologies in Medicine and Biology*, 587-592, 2000.
- Mannion, A. and Troke, M. "A comparison of two motion analysis devices used in the measurement of lumbar spinal mobility." in *Clinical Biomechanics*, vol. 14, 612-619. 1999.
- Giansanti, D. Mecellari, V., Maccinoi, G., Cappozzo, A. "Is it Feasible to Reconstruct Body Segment 3-D Position and Orientation Using Accelerometric Data?" in *IEEE Transactions on Biomedical Engineering*, vol. 50, no. 4, 476-483. 2003.
- Ochi, F., Ave, K., Ishigami, S., Otsu, K., Tomita, H. "Trunk Motion Analysis in Walking Using Gyro Sensors." in *Proceedings 19th International Conference – IEEE/EMBE*, vol. 4, 1824-1825. 1997.
- Guangyan, L. and Buckle, P. "Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods." in *Ergonomics*, vol. 42, 674-695. 1999.

# Images

- dentsim.jpg: Multimedia Simulation Clinic. 2007. Case Western Reserve University School of Dental Medicine. 08 Sept. 2007 <<http://dental.case.edu/admissions/dmd/images/dentsim5full.jpg>>
- posture1.jpg: Loupes. 2007. Royal Dental Group. 08 Sept. 2007 <<http://www.royaldentalgroup.com/images/posture1.jpg>>
- posture2.jpg: Loupes. 2007. Royal Dental Group. 08 Sept. 2007 <<http://www.royaldentalgroup.com/images/posture2.jpg>>
- goniometer.jpg: Occupational Therapist Assistant/Physical Therapist Assistant. 2007. Student Services SIAST. 08 Sept. 2007. <<http://www.siastr.sk.ca/success/images/graphics/goniometer.jpg>>
- PAI.jpg: SIMMER-BECK, M. and BRANSON, B. "Posture Perfect", Dimensions of Dental Hygiene. 2007. Belmont Publications, Inc. 08 Sept. 2007 <[http://www.dimensionsofdentalhygiene.com/uploadedImages/Magazine/2005/05\\_May/Features/14a.jpg](http://www.dimensionsofdentalhygiene.com/uploadedImages/Magazine/2005/05_May/Features/14a.jpg)>
- loupes.jpg: Preface Dental Loupes by SwissLoupes. 2007. SandyGrendel. 08 Sept. 2007 <<http://www.surgical-telescopes.com/images/dentist1.jpg>>
- inclinometer.jpg: SCA103T Series. 2007. VTI Technologies. 08 Sept. 2007 <<http://www.vti.fi/en/products-solutions/products/inclinometers/sca111t-121t-modules/>>