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Static and Cyclic Performance Evaluation of Sensors for Human Interface Pressure Measurement

Jeffrey G. Dabling[1], Anton Filatov[2], Jason W. Wheeler[1]

1. J.G. Dabling and J.W. Wheeler are with Sandia National Laboratories, Albuquerque, NM 87185 USA.
2. Anton Filatov is a Ph.D. student at the Colorado School of Mines, Golden, CO 80401, USA.

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Introduction

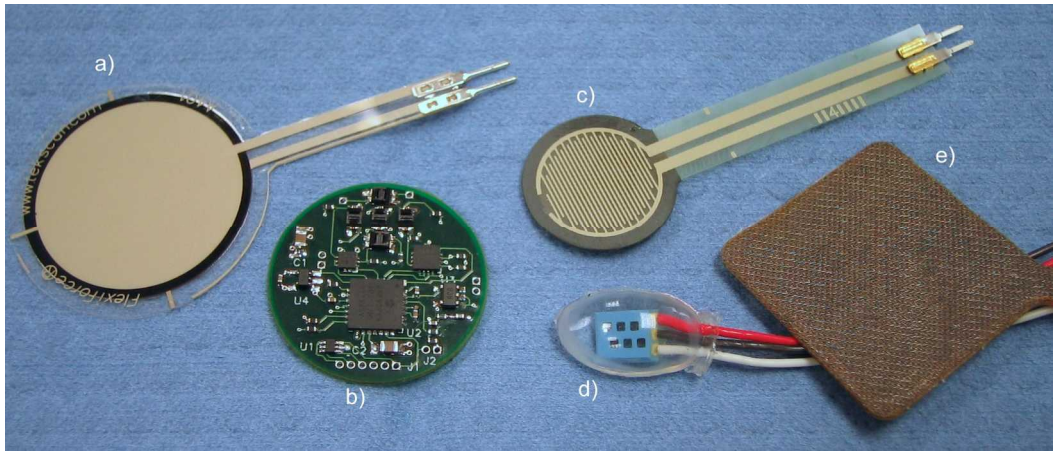
- Measurement of interface pressures between soft tissues and mechanical devices (e.g. prosthetic sockets, orthotics, shoe soles) can be useful for research and clinical applications.
- Often taken with commercially-available sensors, such as FSRs, which are inexpensive, easy to implement, but have well-documented performance limitations. [Buis, Covery, 1997], [Hollinger, Wanderley, 2006]
- We have evaluated the performance characteristics of several different types of tactile sensors, focusing on sensitivity, linearity, noise, hysteresis, and drift.

A. Buis, and P. Covery, Calibration problems encountered while monitoring stump/socket interface pressures with force sensing resistors: techniques adopted to minimize inaccuracies, Prosth. And Orthot. Int., vol. 21, pp 179-182, 1997.

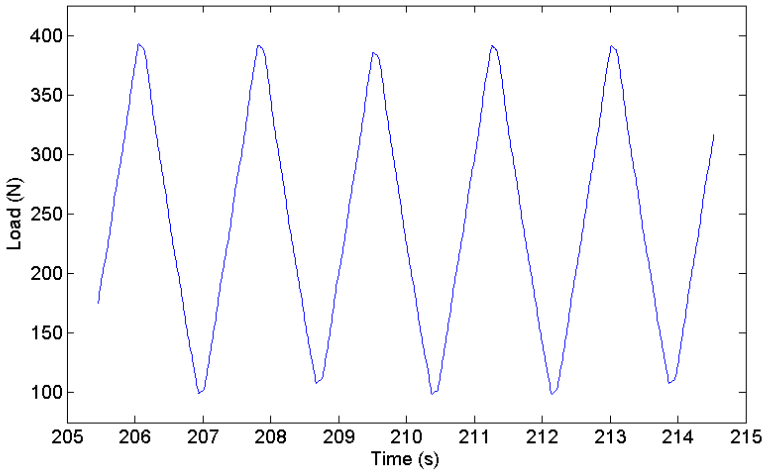
A. Hollinger, and M. Wanderley, Evaluation of Commercial Force-Sensing Resistors, in 2006 Proc. New Interfaces for Mus. Express., Paris, 2006.

Test Methods

- Evaluated sensors: a) Flexiforce by TekScan; b) Sandia Optical 3D force sensor; c) Interlink FSR; d) Sandia Bubble sensor; e) Pressure Profiles C500 capacitive sensor. [Wheeler, et al., 2011]
- Tests Run:
  - Static Drift Test for 13-20 hours
  - Cyclic Loading Test for 4 hours



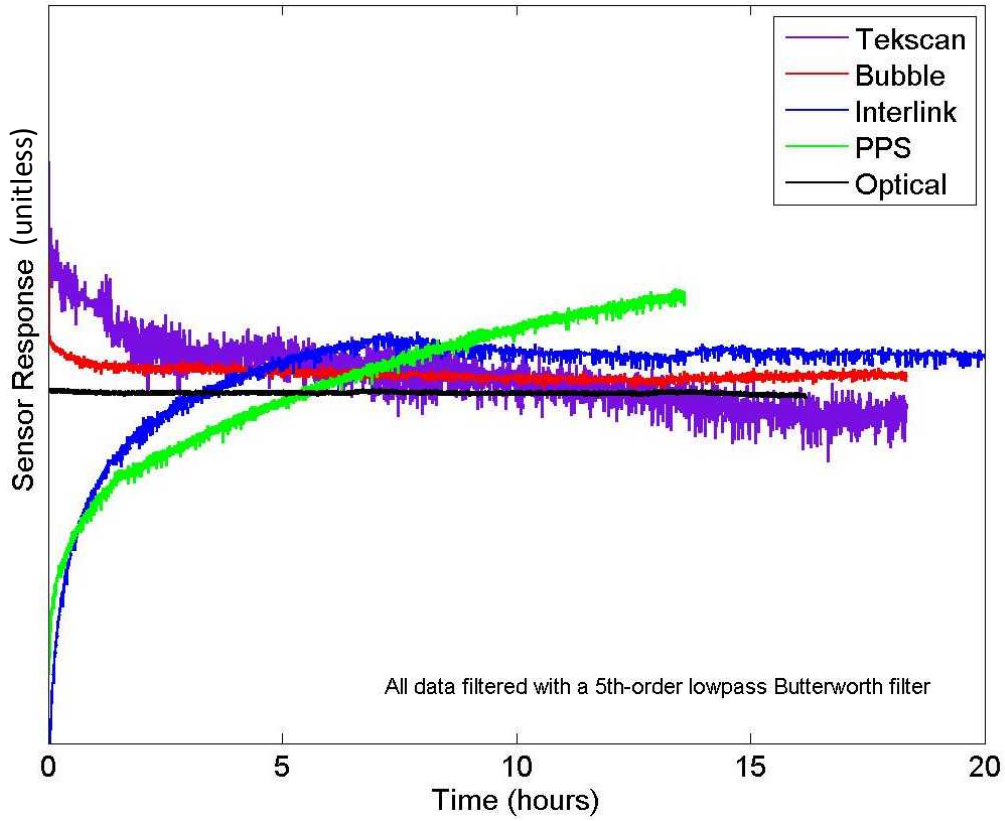
Cyclic loading profile:



J.W. Wheeler, J.G. Dabling, D. Chinn, T. Turner, A. Filatov, L. Anderson, and B. Rohrer, MEMS-Based Bubble Pressure Sensor for Prosthetic Socket Interface Pressure Measurement, in Proc. 33rd Ann. Int. Conference of the IEEE Eng. in Med. And Bio. Conf., Boston, 2011.

Results – Static Drift

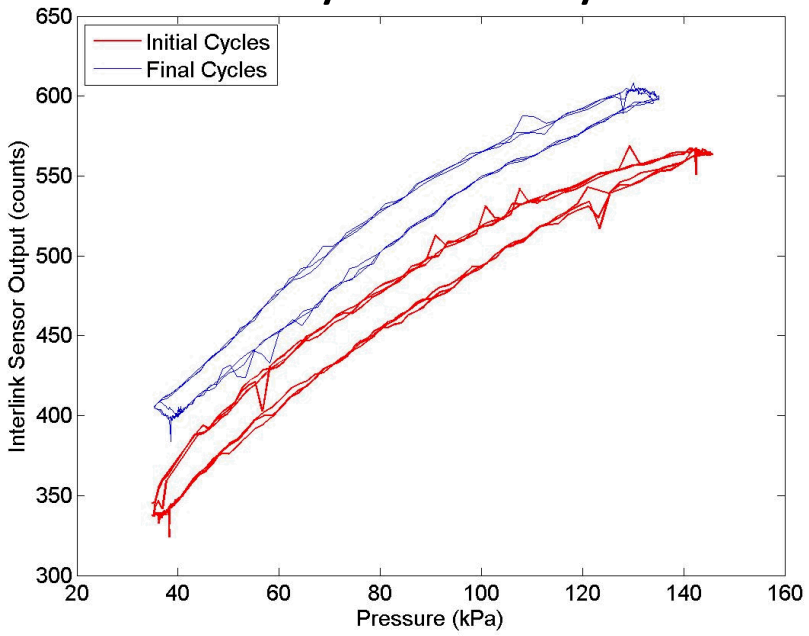
- PPS and Interlink exhibited the largest drift. PPS continued to drift after several hours.
- Sandia Bubble Sensor had the smallest drift.

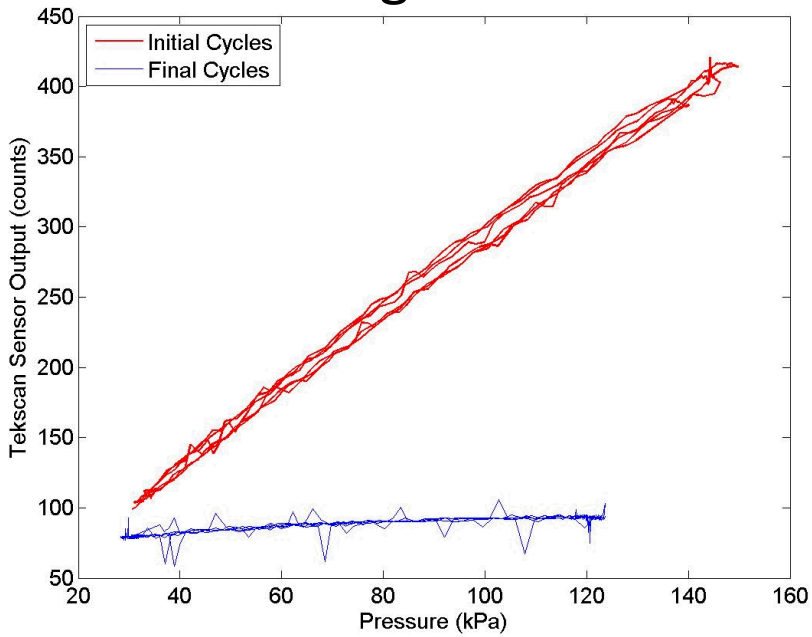


Data shown were shifted (not scaled) to facilitate comparison. Low-pass filtered at 0.1 Hz

Results – Cyclic Loading

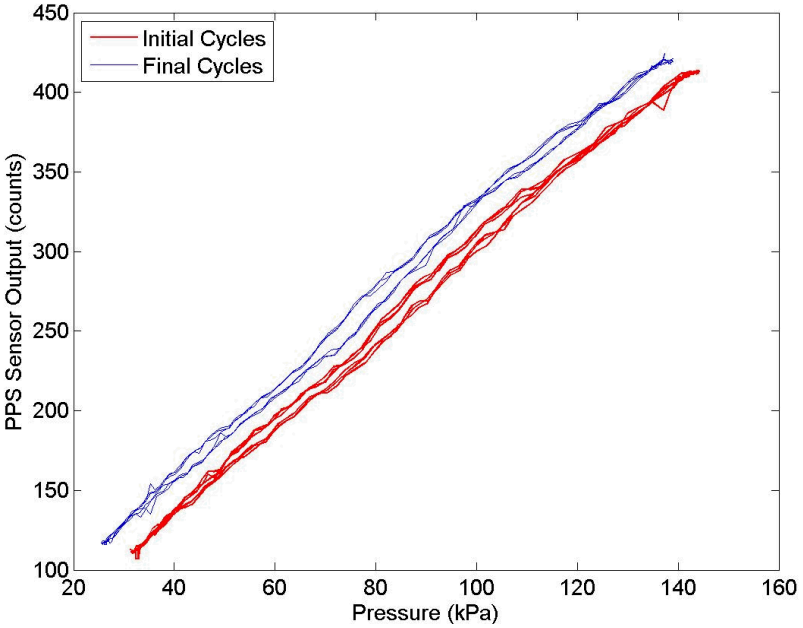
- Figures show a few cycles at the beginning (red) of the test, compared to a few cycles at the end (blue) of the test.
- Interlink showed significant non-linearity, hysteresis, and drift.
- Tekscan started out well, but sensitivity went to near-zero after several cycles. May be due to lack of unloading.

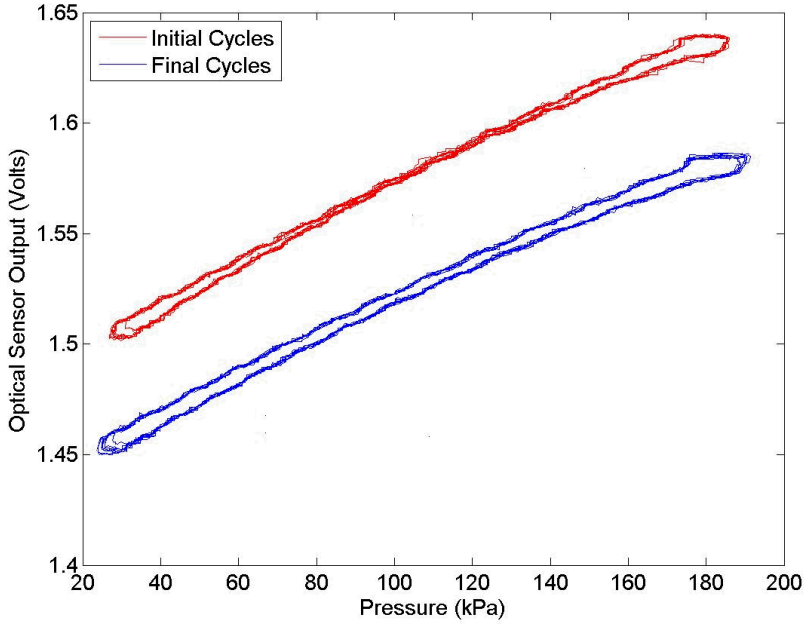




Results – Cyclic Loading

- PPS exhibited good sensitivity, linearity, and low hysteresis, but had moderate drift.
- Sandia Optical sensor exhibited some hysteresis, but substantial drift. Later determined the drift was due to temperature changes. [Lincoln, et al., 2012]

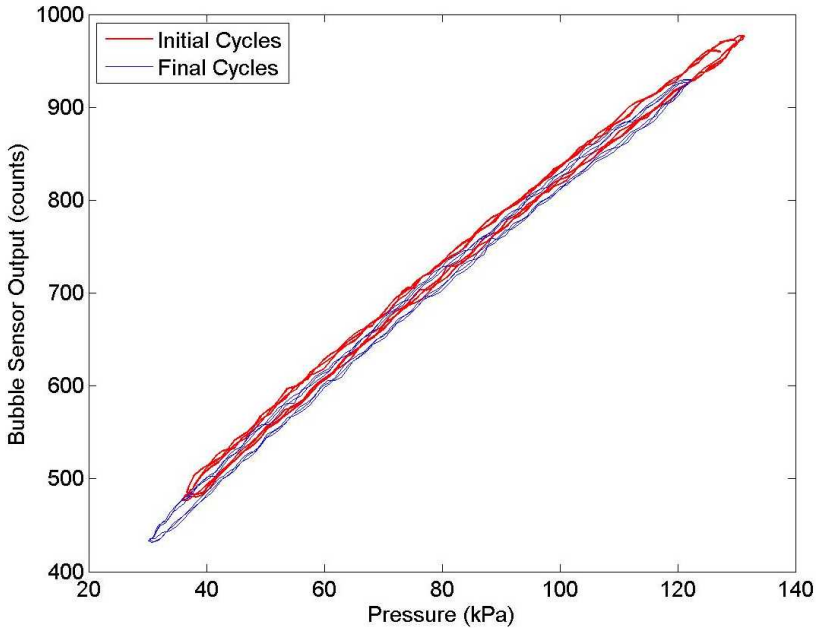




L.S. Lincoln, M. Quigley, B. Rohrer, C. Salisbury, and J.W. Wheeler, An Optical 3D Force Sensor for Biomedical Devices, 4th IEEE Int. Conf. on Biomed. Robotics and Biomechatronics, Rome, 2012.

Results – Cyclic Loading

- Sandia Bubble exhibited good sensitivity, low hysteresis, and very little drift. All cyclic loading tests were displacement controlled, so the applied load drifted some during the test, which is reflected accurately in the results shown.
- Summary table shows numeric results for all tests.



Data Summary for all tests. Values in Percent.

Sensor	Static Drift	Hysteresis	Cyclic Drift
Interlink	21.4 (20 hrs)	19.8	20.9
Flexiforce	6.2 (18 hrs)	7.4	n/a
PPS	24.3 (13 hrs)	6.8	14.3
Optical	4.7 (10 hrs)	13.6	26.8
Bubble	2.3 (18 hrs)	2.8	1.8

Conclusions

- The present work demonstrates the relative strengths and weaknesses of various tactile sensor technologies for use in human interface pressure monitoring applications.
- FSRs (Flexiforce and Interlink) had substantial performance limitations, particularly when loaded in a cyclic manner. Hysteresis may be manageable with software modeling, but drift is difficult to overcome, and may require frequent recalibration.
- PPS had good sensitivity, linearity, low hysteresis, but drift may be prohibitive when used for prolonged periods. They are also relatively expensive.
- The Sandia Optical Sensor had reasonable performance, although it exhibited some hysteresis and significant drift, which can be compensated for with on-board temperature sensing. The main advantage is the ability to measure shear, which isn't possible with commercial tactile sensors.
- The Bubble sensor had the best overall performance. Low hysteresis and drift make it very attractive for many applications. However, the non-flat profile requires special packaging considerations.