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AN OPTICAL 3D FORCE SENSOR FOR BIOMEDICAL DEVICES

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Background and Motivation

In many biomedical applications, it is useful to measure normal and shear pressures. For example, prosthetics hands could use tactile sensing to aid manipulation and grasping or to provide feedback to the wearer. In prosthetic sockets, monitoring interface loads can provide indications of poor fit or other problems to amputees (who may be insensate) or clinicians. The vast majority of tactile sensors used for these applications can only measure normal pressure. Shear sensing is most commonly done with strain gauge-based load cells, which are generally large and expensive. We have developed a low-profile optical tactile sensor that can measure both normal and shear pressures.

Principle of Operation

The sensor uses optical emmitters and detectors to measure the strain in elastomeric materials. A transparent layer of elastomer is used as the sensing medium. Layers of opaque elasomer with rellective and absorptive patterns are placed above the transparent layer. The amount of relefected light to the photodecectors changes with strains in the elastomer layers.

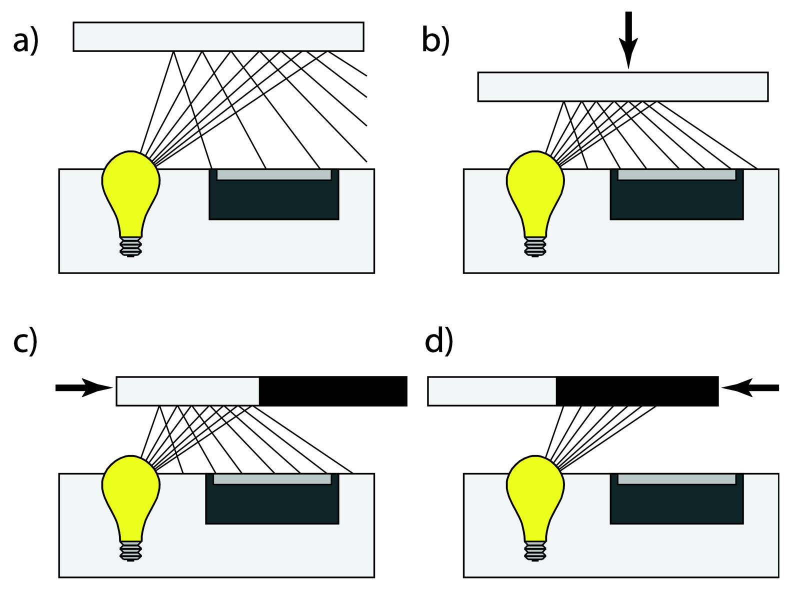

Figure 1: Sensor principle of operation. The amount of reflected light to the photo detector varies as the opaque elastomer layer moves in three directions.

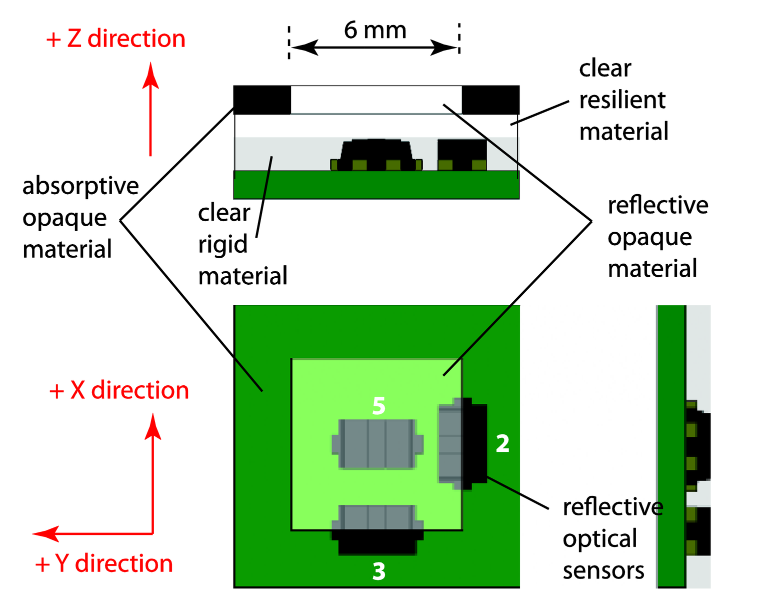

Figure 2: Sensor construction. Photomicrosensors are placed on a PCB with epoxy and transparent and opaque elastomer layers. The opaque layer consists of regions of reflective and absorptive materials.

Sensor Construction

The optical emitter/detector pairs are integrated circuit components mounted on a printed circuit board (PCB). An optically clear epoxy covers the electronics up to their height. A transparent layer of 10 Shore A silicone (1-2 mm thick) is molded above the epoxy. An opaque layer of silicone of arbitrary thickness is then molded above the transparent layer. Current systems use 3-5 emitter/detector pairs and a square pattern of white/black on the opaque layer.

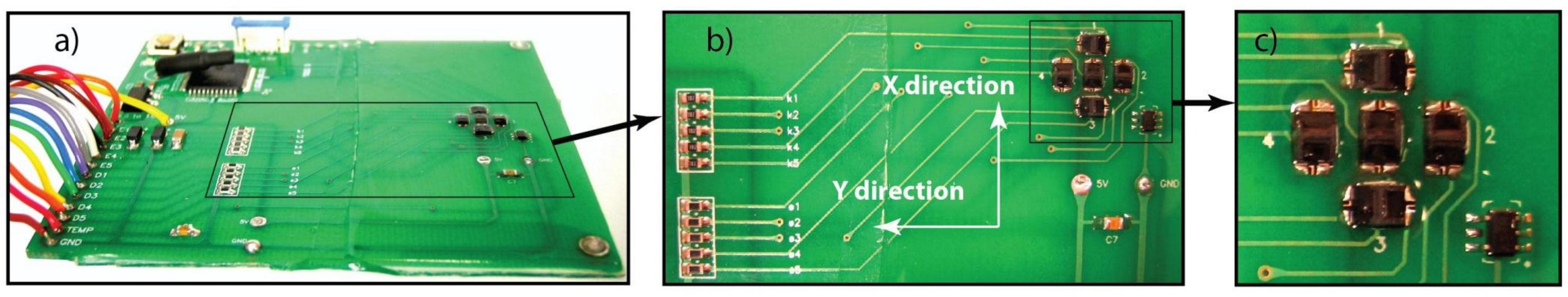

Figure 3: Printed Circuit Board with photomicrosensors and temperature sensor for compensation. Epoxy and elastomer layers are poured on top of the board.

Sensor Characterization

The sensor was tested using a custom, 3-axis stage with an ATI Gamma Force Transducer in series. Displacements were applied manually and the sensor response was recorded along with the true force values. The sensor was tested for sensitivity in all axes, drift, hysteresis and dynamic response

Results

The sensor showed good sensitivity, primarily in the shear directions with minimal coupling between axes. The dynamic response was adequate for the proposed applications. Some drift and hysteresis are evident. The drift is primarily due to temperature effects and current systems utilize on-board temperature compensation.

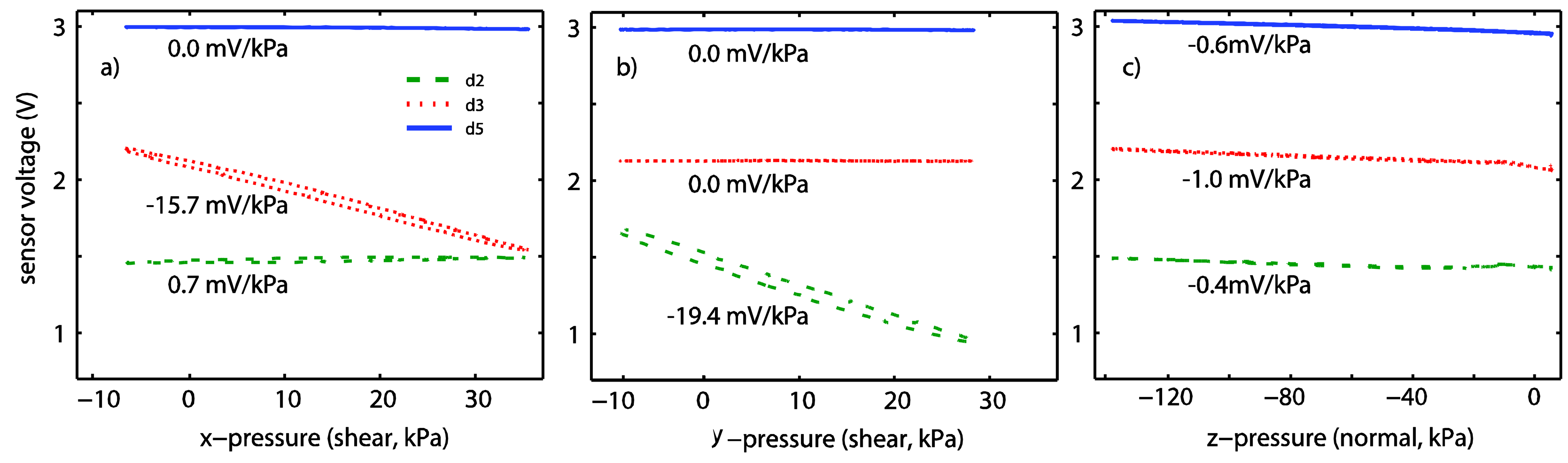

Figure 4: Sensor response to loads in X, Y and Z directions. Shear sensors are primarily sensitive to loads in one direction. All sensors respond to normal loads to some degree.

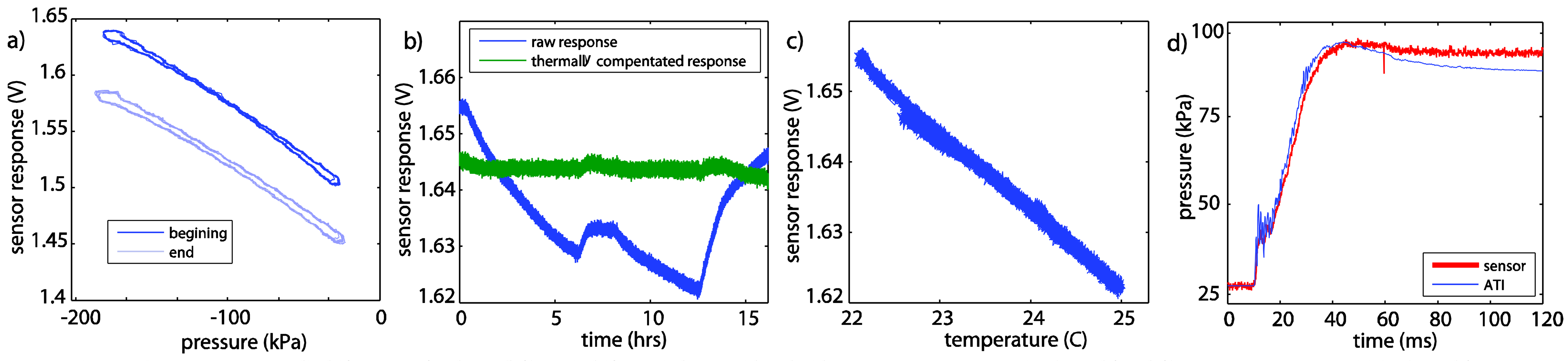

Figure 5: Sensor response to cyclic drift test over four hours (left), static drift over 15 hours with and without temperature compensation (second from left), sensor temperature sensitivity (second from right) and dynamic response to a step input (right).

Sensor Calibration

Displacements were applied in all three directions simultaneously and sensor response and true force were measured. A linear regression was used to train the sensor response to the true force. This calibration was applied to a new trial and compared to the load-cell response.

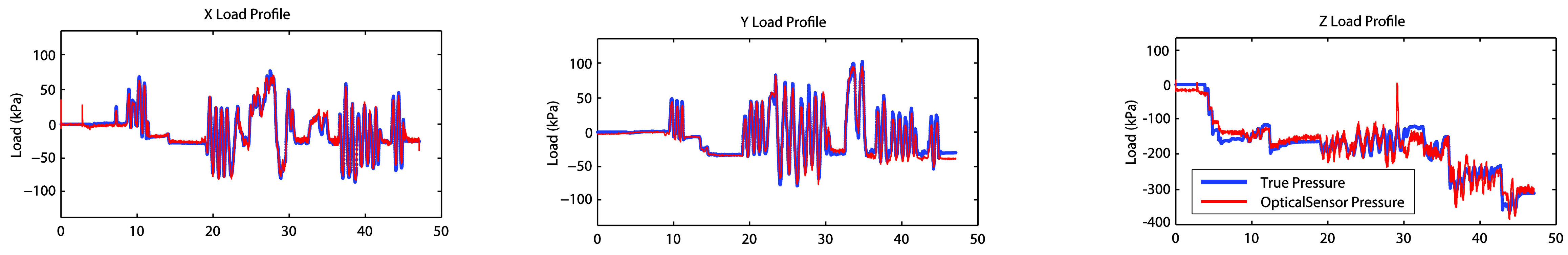

Figure 6: Trained sensor response to multi-axis loads. Sensor was trained with a linear regression and refit and compared to ATI load cell data.

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