Minimally Invasive Gathering of Body Context Information from Garment Interactions

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Abstract

This paper describes recent work using pressure-sensitive polypyrrole-coated foam to gather body context information from the pre-existing dynamic physical forces between the wearer's body and a smart garment. The test configuration used foam to monitor breathing, shoulder movement, neck movement, and constant pressure on the shoulder blades. This study was conducted to evaluate the utility of the polypyrrole sensor in detecting dynamic body-garment interactions, for use in future work. Unobtrusive, garment-integrated context-awareness is minimally invasive for the user: there are no inherent requirements for precise positioning, skin contact, or restrictive garments.

1. Introduction

Many ubiquitous and wearable computing applications rely on the availability of context information describing the physical state of the wearer. Indeed the availability of such information has the potential to greatly reduce the cognitive load imposed on the user or inform the operation of an ambient system. Information related to the wearer's context can often be inferred by monitoring the physical state of the wearer directly – including physiological signals, movements, and body state – by integrating the appropriate sensors into a garment. Unfortunately, many of the existing sensing technologies used to obtain this kind of data cannot be easily integrated into a garment structure in a way that preserves its wearability and comfort properties. Very often, for example, the user must don constrictive apparatuses to maintain consistent sensor positioning, adhere sensors to the skin, or endure the discomfort of bulky, solid, protruding sensor structures.

This research is focused on evaluating and understanding the potential of innovative new sensor techniques for gathering context awareness information in a minimally obtrusive manner: instead of monitoring changes in limb position or body length or circumference measures, information was gathered from the pre-existing dynamic physical forces that operate between the wearer's body and a garment during physiological functions or movements.

In this study, a soft, washable, pliable pressure sensor was used to monitor dynamic pressure data from a subject. The sensor, which is made from standard polyurethane foam with a conductive polyprrole coating, retains all of the physical properties of regular polyurethane foam, and is washable (Brady et al, 2004). Importantly, this sensor technology can be readily embedded into a "normal" garment, retaining the structural and tactile properties of a textile structure, while at the same time, gathering data from changes in the wearer's state, which arise out of everyday movements.

2. Garment Structure

In this initial study, a test garment was constructed to house the foam sensors. This garment was a sleeveless, collared shirt, closely fitted and nonextensile. The outer garment layer was a 100% polyester satin weave, and the inner layer was a 100% acrylic satin weave. The collar was 80% nylon, 20% elastine jersey knit. The structure of the garment was crucial to the quality of data obtained, as its textile composition, design, and fit moderated the amount of force present between the body and the sensors. In this study, the prototype garment was fitted to one test subject, to eliminate inter-subject anthropometric variation.

The test garment contained foam sensors in 6 locations: the top outer edge of each shoulder, the back of the neck, the superior protrusion of each scapula, and the right side rib cage, under the bust (Figure 1.) Sensors were sewn between the two garment layers, allowing them to be easily removed and interchanged.

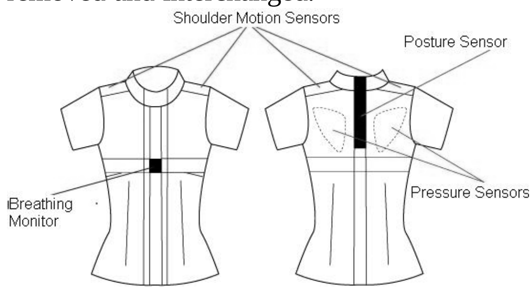

Figure 1: Garment Structure and Sensor Layout

3. Sensor Tests

Sensor positions were chosen to test the foam reaction to 4 different actions: breathing, shoulder movement, neck movement, and shoulder-blade pressure. In each test two wire leads were attached to the foam sensors and to a digital multi-meter. The dynamic resistance of the foam was measured directly: the data presented here contains no post-processing or filtering.

3.1 Breathing

As seen in Figure 2, deep breathing resulted in a sinusoidal resistance curve, varying between approximately 2K and

4K Ohms. These are low values and a low total change compared to the other sensors. This is a result of the age of the foam: the breathing sensor was replaced with week-old foam prior to the test, while the other sensors were 2 months old. The polypyrrole coating oxidizes gradually over time, decreasing the conductance of the sensor. The sensor output appears to be sufficiently robust, even in its unfiltered state, for a reliable determination of the wearer's respiratory rate, for example.

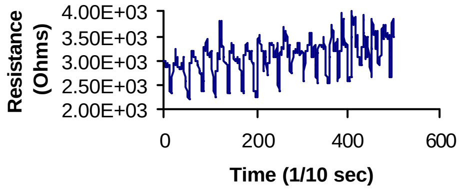

Figure 2: Resistance Reaction to Deep Breathing

3.2 Shoulder Movement

To test shoulder movement, the subject repeatedly raised her right shoulder to its maximum height. The result was a decrease in resistance from approximately 500 KOhms to approximately 50 KOhms, as seen in Figure 3. Once again the data appears sufficiently robust to reliable detect each shoulder movement; however no test was performed to detect the foam reaction to shoulder movements of varying magnitudes.

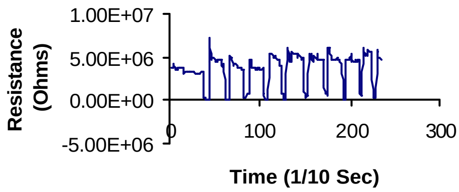

Figure 3: Resistance Reaction to Shoulder Lift

3.3 Neck Movement

The neck bend test consisted of four full neck extensions (backwards movement) and three full neck flexions (forward movement). The foam responded with a decrease from approximately 1-1.5 MOhms to approximately 50KOhms for the full extension, and from 1.5 MOhms to approximately 1 MOhms for the full flexion, as seen in Figure 4.

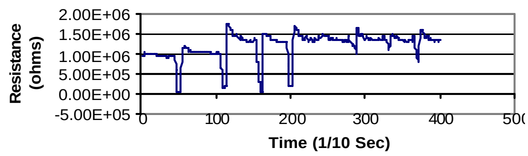

Figure 4: Resistance Reaction to Neck Movement

This data indicates that the dorsal neck sensor placement exhibits a response of greater magnitude for extension than for flexion. Since the sensor provides no additional qualitative information, it is hypothesized that a second sensor would be required to determine the difference between a small extension and a large flexion.

3.4 Shoulder-Blade Pressure

To test the reaction to constant pressure on the scapula, the subject lay supine (face up) on a hard tile surface, then sat up, and repeated the process once. The foam responded with a decrease from approximately 300 KOhms to approximately 100 KOhms when pressure was applied to the scapula, as seen in Figure 5. This relatively lower baseline resistance (300 KOhms) is due to the larger area of the shoulder blade sensor: 32cm^2 for the shoulder blade sensor versus 3-12 cm^2 for the other sensors.

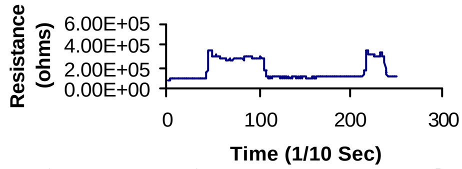

Figure 5: Resistance Reaction to Constant Scapula Pressure

4. Conclusions

Based on this preliminary data, polypyrrole-coated conductive foam shows considerable promise as a basic sensing technology, and for use in detecting body movements, physiological functions, and body state from body-garment interactions. Importantly, the sensor maintains the attractive structural properties of foam, consistent with the objectives of wearability and comfort in a smart garment.

Further study is necessary to fully understand the ability of the foam to serve as a reliable sensor over time and under the hostile conditions that garments must usually face. For instance, further work is required to understand and determine the effects of oxidation on baseline drift, the influence of variable conductance responses, and the optimal locations for sensors. In addition, processing algorithms for extraction of patterns from gathered data are required, as well as wearable hardware to allow the data to be used in real-time.

Future work includes in-depth analysis of foam responses to controlled movements, and evaluation of optimal sensor location for monitoring of specific activities.

5. Acknowledgements

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6. References

Brady, S., Diamond, D., and Lau, K. "Inherently conducting polymer modified polyurethane smart foam for pressure sensing". *Journal of Sensors and Actuators A.* In Press.