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DOI
10.1145/3211960.3211969

Publication date
2018

Document Version
Accepted author manuscript

Published in
WearSys 2018

Citation (APA)
Jansen, K., Tarren, B., & Slingerland, M. (2018). Disposable, stretchable on-skin sensors for posture monitoring. In *WearSys 2018 : Proceedings of the 4th ACM Workshop on Wearable Systems and Applications* (pp. 1-4). Association for Computing Machinery (ACM). https://doi.org/10.1145/3211960.3211969

Disposable, stretchable on-skin sensors for posture monitoring

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Abstract

We developed disposable and stretchable on-skin sensors for simple and unobtrusive monitoring of posture and movements during daily activities. Simple sensor platforms like these are expected to become commonly accepted in the near future, not only for posture monitoring but also for e.g. motion monitoring in sports. The paper describes the development and preliminary testing of the sensor platform.

CCS Concepts

• **Measurement techniques → Sensors**

Keywords

Skin sensor, health monitoring, posture

1. Introduction

Bad posture is a prolific problem across the globe. Poor posture is highly linked to interaction with technology (like mobile phones and iPads). In today's society, that means the large majority of us is likely to suffer from poor posture. Positioning in miss aligned postures for extended periods of time create muscular imbalances [1,2]. These imbalances strengthen certain muscles, while the opposing muscles weaken. Because of this, imbalances are cyclical, once created, people are more likely to continue the imbalance due to the strengths/weaknesses of your musculature. Therefore a solution to help users to maintain awareness of their posture is needed.

Solutions for posture awareness and personal health monitoring exist on the market today in the form of braces, external wearables, textile corrective or sensing products [3]. These products tend to use conventional electronic materials with a low biocompatibility. In addition to being rigid, conventional electronic materials fail at 1-3% strain, when human skin undergoes strains of around 30%, and as much as 100% at joints.

For sensors to be accepted by users during their daily life activities the main requirements are that they are simple to use, robust and unobtrusive. In the present paper we will discuss the development of a highly stretchable on-skin strain sensor which can be used for posture monitoring as well as for supplying feedback during rehabilitation and detailed movement monitoring during sports and fitness activities.

2. Sensor development

The development of soft sensors has sped up to match the growing demand of applications such as personalized health monitoring, human motion detection, human-machine interfaces, soft robotics, and more [3]. Such systems designed to be placed on the human skin can be called "sensor skins" [4-6]. These wearable sensor skins have ultra-thinness, low modulus, light weight, high flexibility, and stretchability, and are in direct contact with the skin [3]. Their sensing capabilities enable monitoring of e.g. the heartbeat, the jugular venous pulse, muscle movement, bodily motion and temperature.

A sensor that does truly match the human body's biomechanics is Duoskin. Created by the MIT Media Lab, Duoskin tests the use of gold metal leaf for touch input, displaying output and wireless connection sensing [7]. It is based on a tattoo like platform and is therefore also disposable. A disadvantage is that it is quite delicate and can easily fail.

Here we explore the use of a stretchable plaster as the substrate for the sensor. Stretchable plasters are well known in the form of kinesiology tape (KT tape) used by athletes [8,9] (see Fig.1).

Figure 1. KT tape on athlete

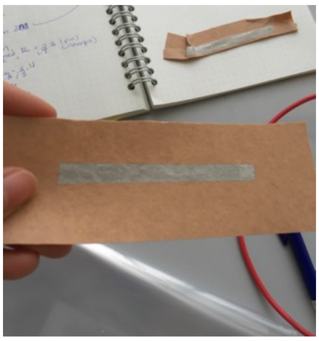

Figure 2. 9907T tape of 3M with conductive ink layer

These tapes are strong, have a good adhesion to the skin and are highly stretchable (over 100% strain). They are, however, relatively expensive and have a rough, open weave surface structure which disrupted the uniform application of the sensor inks. As an alternative we therefore used the 9907T tape of 3M (Fig.2). This tape had a comparable stretchability and adhesion but a much more uniform surface structure

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On top of the 9907T tape we applied Dupont's new stretchable silver conductive ink (Dupont PE873) using a doctor blade. This resulted in a uniform conductive layer on the tape substrate which remained conductive even after 50% stretching. By monitoring the resistance changes this allowed us to follow the local skin stretching and thus the movement of body parts. During the initial stretching tests it was noted that small cracks were formed at higher elongations. In order to make the device more robust several ways of creating more parallel conductive paths were considered with the idea to increase the redundancy: if a crack disrupts a conductive path now the other paths take over. The different ink patterns studied are shown in Figure 3. The final design of the disposable on-skin sensor is shown in Figure 4.

In the next part we discuss the calibration of the sensor.

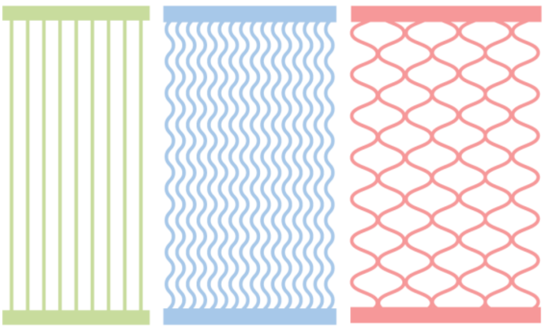

Figure 3. Ink patterns studied to increase the path redundancy

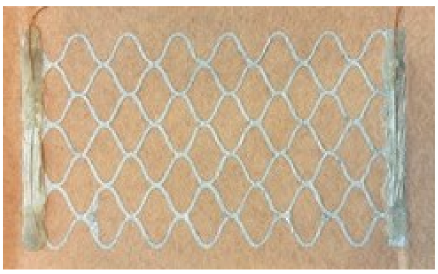

Figure 4. Disposable on-skin sensor with wave pattern

3. Sensor testing

The sensor of Figure 4 was first tested on a standard Zwick tensile tester (Zwick Z010) and resistance changes were measured as a function of time (Figs.5 and 6). It turned out that the recorded signal always showed a spike just after loading and that for the wave pattern (3rd option in Fig.3) these spikes were considerably lower than that for the wiggle pattern (2nd in Fig.3).

Figure 5. Sample in tensile tester

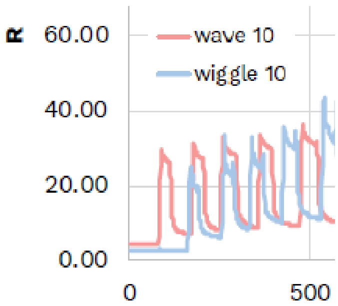

Figure 6. Measured resistance changes

Next, it was tested how the sensor behaved when applied directly on the body. In order to have an independent way of measuring the skin deformation we used a 3D motion capture camera system which recorded the positions of silver markers attached to the backs of test persons (Fig.7). All test persons were asked to go through a standardized cycle of postures. These postures are taken from a study done by furniture company Steelcase on postures connected to technology use (examples are given in Fig.9 and 10). In between these postures the test persons were ask to return to a well-defined reference position. A trained physical therapist was present during the measurements to give instructions and correct if necessary. Each posture was maintained for 5 seconds. The measured changes in marker distances were converted to local strains and represented as a strain map (Fig.8).

From this data the area in between the shoulder blades was selected as a representative place for measuring posture changes. In a follow up study a strain sensor was placed in between the shoulder blades of the same test persons. By analysing the data it was found that there was a notable 8% offset effect of the sensor data which was attributed to a pre-stretch of the sensor during application. In the data comparison of Fig.12 this is shown as the black bar parts of the sensor data. Taking into account the above-mentioned offset, it can be seen that the simple disposable sensor data correlates well with the calibration data obtained from the 3D optical measurements of marker displacements. Moreover, it can be seen that the sensor can be used to discriminate between most of the different postures.

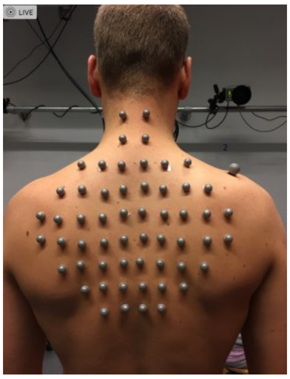

Figure7. **Setup for optical skin stretch measurement**

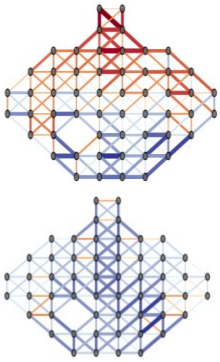

Figure 8. **Typical results optical measurement**

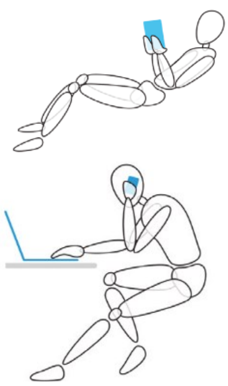

Figure 9. **poses 1 and 2**

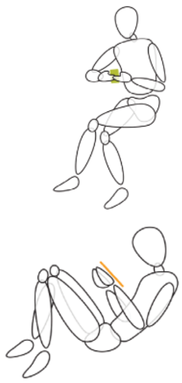

Figure 10. **Poses 3, 4**

Figure 11. **Sensor attached to test person**

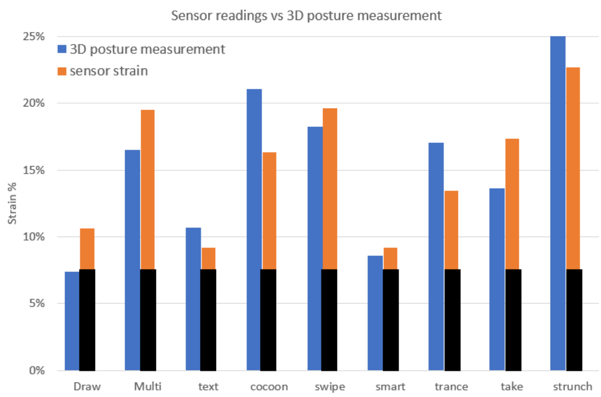

Figure 12. **Comparison of measured strains. The first 4 poses correspond to those indicated in Fig.9 and 10**

4. Conclusions

A new and simple way of producing a disposable on-skin stretch sensor was presented using a stretchable tape in combination with a stretchable conductive ink. The skin stretching of this sensor when attached to a test person was compared to optically measured skin deformations for a set of 9 standardized postures.

A comparison showed that the stretching of the sensor during application caused a marked offset in the data but if this is taken into account the sensor showed good agreement with the optical measurements.

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