TRAINWEAR: a Real-Time Assisted Training Feedback System with Fabric Wearable Sensors

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TRAINWEAR: a Real-Time Assisted Training Feedback System with Fabric Wearable Sensors

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***Abstract*—In this demonstrator, we present Trainwear, a wearable garment that utilizes fabric pressure sensing for sport exercise activity recognition and feedback. The shirt emphasizes on design for public users using our developed sensing technology. A video of the demo is linked at the end of this technical paper.**

***Index Terms*—wearable computing; fabric pressure sensing; digital sport.**

I. Introduction

Nowadays, fitness wearable garments have been largely limited to solid integrated circuit sensors such as IMU, optical heart-rate sensor, etc. The information from the said sensors are limited to movements of where the solid sensors are attached. In this demo, we present fabric based sensors as an alternative input for fitness garment, and presenting a complete system for user feedback.

Alternative textile sensors have received little market acceptance so far, which is partly contributed by the little design effort in recent research prototypes. While scientists and engineers focus on making perfectly functioning systems and proven algorithms, we typically do not work with fashion designers who are experts at creating publicly acceptable apparel designs. The scientific foundation of the fabric sensing technology in our demonstrator has been exhaustively studied in our previous works in the pervasive computing community [1], [2],[3]. In this demonstrator, we focus on the integration of the sensing technology into normal-looking shirts, information visualization and audio-visual feedback. The demonstrator is aimed at improving the acceptance by public users of our existing sensing technology, therefore, a lot of design elements are included.

The fabric sensors measures the pressure on the fabric, which can be related to muscle activities as we published in [3]. As shown in Fig. 1, the sensors cover across left and right chest muscles and biceps. When the wearer is doing repetitive exercises, the sensor will generate a pressure map of each individual point over the fabric surface, spaced at $1.5cm$, an example of the average surface pressure from each muscle group is displayed in Fig. 2 in the four square blocks in the corners.

From the data format, according to our previous studies on sport activity recognition with the same surface pressure mapping principles [3], [2] and our observation with this shirt prototype, after calibration to match the signal ranges between the left and right side, the temporal features of the pressure mapping can tell us about the user's activity such as:

- balance between the left and right average pressures;
- speed, based on peak to peak distance;
- range of motion, based on the depth of the curve.

II. Hardware

A. Textile integration

This section is to describe our process of creating a smart textile shirt which looks as normal as possible. The only rigid part of the sensing system is the 3D printed box which holds the electronics, we decided to place the boxes on the shoulder as a shoulder badge, covering it with a textile enclosure which is secured by velcro. This placement is also a result of considering the fact that over the shoulder, the bone is not covered by much muscles, therefore typically people do not load weight at these areas (for example, with a normal barbell squat, the bar is usually carried over the upper back instead of directly on the shoulder bone). The sensors for the chest are placed at a place where the least elongation would occur while the wearer is doing various exercises, since the fabric sensor is not stretchable. The chest sensors each has 16×4 sensing points, and the biceps each 10×4, resulting in 208 sensing points over the said muscle groups.

To minimize the cables routing over the body, we place two electronic modules, each is connected to the chest and biceps at the same side, even though one module alone is sufficient to power all sensor patches. Therefore, the cables which are also not stretchable are routed over the shoulder and the upper part of the ribs.

From the design and aesthetic point of view, red textile patterns are sewn on the surface over the sensor patches as shown in Fig. 1 (a), therefore covering any visible sewing tracks while securing the sensor patches. Logos are printed with a red accent on letters ”ai” to indicate the artificial intelligence and wearable technology under the hood.

The wearer can perform all sorts of exercises including push-ups, biceps curls, handstands, etc. without the sensor system getting in the way.

B. Electronics

The electronics is built around a dsPIC which supports scanning a sensor matrix of up to 32×32. Data is wirelessly transmitted with Bluetooth Classic, with up to $150Hz$ of

(b)

(a) (c)

Fig. 1. views of the Trainwear shirt: (a) frontal view, (b) inside frontal view, (c)back view while worn by the user.

Fig. 2. the graphical user interface

the sensor dimensions on the shirt. Under continuous operation, the electronics consume around $100mA$ current, with a $800mAh$ Li-Po battery, the system can operate for 8 hours on a single charge; under-voltage shut down is also implemented to protect the battery.

III. Software

In this demo, our system is implemented on a PC under Windows operating system, while the code can be easily deployed on macOS or Linux since we used only Qt C++ and HTML with Javascript. The Qt C++ backend simply receives and saves the data from Bluetooth at its native speed ($150Hz$), and send out to an user interface that is implemented in HTML which runs from a browser. In our work of [2], an Android program was also implemented for the same electronics with a soccer shoe, with an Android webview running HTML code for visualizing, therefore an Android port is also easily achievable. The realtime machine learning algorithm can be implemented either in Qt C++, Javascript with Node.js as backend, or python that communicates with the Javascript with communication implementations such as the flask-socketio.

A. UI design

The Qt backend shows the sensor raw data as pressure maps. For public users, we designed a graphical UI as shown in Fig. 2 to present the data more lively and also offer feedback. The goal of the UI is to manifest the presence of the abstract algorithm, data and artificial intelligence. A circle that takes a major part of the screen resembles the algorithms. An "aura" is plotted around the circle, whose "magnitude" on each point at a even angular partition to the circle's outline changes with the real-time sensor point data value. A smaller aura is also drawn whose magnitude changes with several internal variables such as the intermediate values, balance, or feedback sound waves, that generates a "contemplating" feel of the software to the user.

According to the people who have been asked to review the UI with the running hardware, it feels like an entity that is "alive" since it depicts a complex morphing shape which is highly responsive to touching the sensor at different points and the wearer's movement.

Inside the circle, feedback for exercise correction or friendly interaction can be added. The design principle is to keep simple texts and graphical expressions. At the meanwhile, the Javascript also offers audio feedback by text-to-speech. The overall feedback, including the content inside the circle and the audio can be therefore sent to smart glasses for better user experience.

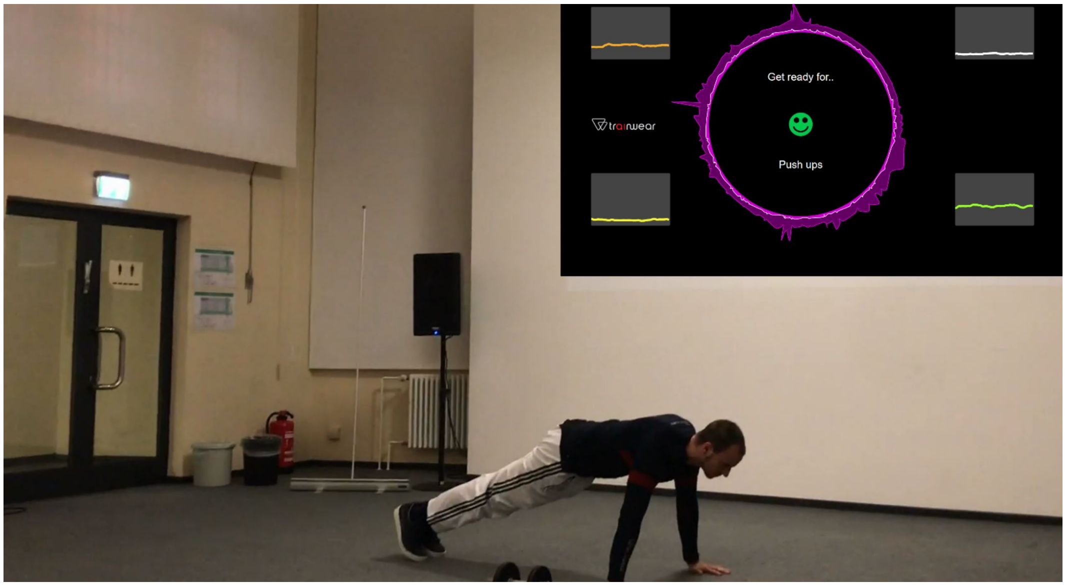

Fig. 3. scene of the demonstration video while the wearer is preparing to do pushups.

Fig. 4. QR code of the url link to the demonstration video https://vimeo.com/198829929

IV. Conclusion

Overall, this demonstrator has created a smart textile garment that is aimed for better acceptance from public users, with a visual-audio feedback system. A short video of the demonstration as shown in Fig. 3 is accessible through $https://vimeo.com/$198829929 or scan the QR code in Fig. 4

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