Smart Rehabilitation Garment Design for Arm-hand Training

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ABSTRACT

This paper describes the design of a smart rehabilitation garment (SRG) to support posture correction during rehabilitation training. The garment is equipped with accelerometers in various positions and is controlled by an Arduino processor. It connects with Bluetooth to a smartphone or a personal computer in order to provide feedback to patients. The garment can provide reminders to users by vibration. We discuss the placement of sensing modules, the garment design and the integration of smart textiles and wearable electronics. The garment has been designed to support posture feedback during rehabilitation training, e.g., in the context of arm-hand training, or to be used as a posture correction aid worn throughout the day. We argue that wearability and comfort are major requirements in order to achieve acceptance by users.

Categories and Subject Descriptors

H.5.m [**Information Interfaces and Presentation**]: Miscellaneous;

General Terms

Design, Human Factors

Keywords

Wearable technology, Arm-hand rehabilitation, Smart Garment design, Smart textiles

1. INTRODUCTION

As the population is aging the need arises to support rehabilitation with technologies in order to provide more efficient and effective therapy, and to support patients to reach their full potential for recovery. Arm-hand rehabilitation plays an important role for multiple rehabilitation process: stroke, spinal cord injury, Parkinson, cerebral palsy etc. [1].

Technology can support training through providing interactive exercises and even games, designed to help the patient practice tasks improving their strength and control. See for example [2], [3]. Due to the long time recovery process, the prospect of using such technologies at home offers the promise of cost-efficiency and of increase in the amount of training, which can in turn improve training outcomes. However, patients who suffered from those serious diseases may have a reduced capability to control their arm-hand, tend to develop compensatory strategies where they use alternative movements and muscle groups to compensate for the diminished capability of their damaged arm. Applying such compensatory strategies during training reduces the training effectiveness.

Currently training with or without technology often relies on therapist supervision, with the therapist reminding the patient to keep the right posture, and providing corrective feedback when the patient moves outside a specific range. This observation suggests the potential utility of posture monitoring and feedback technology that can be used within or outside the context of a specific game. For example, Timmermans et al used sensors on the arm and torso of stroke patients during training with the Philips stroke exerciser [4], in order to ensure the correct execution of exercise. Beursgens et al, developed a vest for monitoring the patient posture while playing a serious game intended to support arm-hand rehabilitation[5], [6].

These systems suggest how wearable sensor technology can be used; here we look to make a device that can be used in many different training approaches, that is not embedded in a specific game or exercise system. Further we consider the potential use of the device as a posture correction aid to be worn through the day, e.g., to prevent or cure low back problems, or in relation to RSI, etc. Thus, we look to improve the engineering and aesthetic qualities of this smart rehabilitation garment.

Paralleling the advances in wearable application in rehabilitation, also provides great superiority for the development of upper-extremity rehabilitation, a number of SRG's aiming at support arm-hand training have been developed [7], [8]. Although wearable technology shows great 'promise and provides many

Figure 1. Example of compensation movement.

REHAB 2014, May 20-23, Oldenburg, Germany

DOI 10.4108/icst.pervasivehealth.2014.255256

technical benefits [9], other aspects like the wearability, the user experience, and the aesthetics are often neglected [10].

In this research, we set out to design an SRG with integrated smart textiles and wearable electronics for encouraging patients' posture monitoring in the context of home rehabilitation. Smart textiles have become a dominant trend in wearable electronics [10], especially in the area of healthcare with the features like: being washable, flexible and lightweight, following current style trends and providing an overall positive and pleasurable experience to the user.

2. SYSTEM CONCEPT AND REQUIREMENTS

We propose a monitoring system that aims to improve motor training quality by sensing the compensation movement with shoulder and torso, as shown in Figure 1. While wearing the garment during rehabilitation exercises, the user can set a target range of motion. When the detected compensation movement is oustide the set value range the user can get vibration feedback.

Following the guidance from therapist and earlier investigations [6], [11], we argue that the design of the garment for posture monitoring and correction should consider the following requirements for both the function and user experience aspects:

- SRG should be easy to put on and off and to wear with normal clothes.
- SRG should be light, comfortable and appropriate for long term monitoring.
- Sensors should fit closely to the body for higher accuracy.
- SRG should provide feedback for monitoring result and system's functioning.
- SRG should be scalable for other modular functions.
- Be adjustable for different size.

Currently our prototype SRG system consists of two parts: a smart sensing jacket and an app on smart phone controls the system also provides graphical feedback. The sensor position is shown in Figure 2, two accelerometers (S1, S2) are placed on the T1 and T5 disks of the spinal column for monitoring trunk movement [12]. The third one is placed on the shoulder of the patients affected side (S3 or S4).

3. PROTOTYPE AND ARCHITECTURE

We propose a modular design consisting in multiple sets of garments and one set wearable sensors. Based on the removable design of the wearable electronics, users can mount the electronics on different garments allowing for choice and comfort. The sensing garment should look friendly and familiar and offer better engagement.

3.1 Components in detail

The system contains three sensor nodes that communicate to two Lilypad Arduinos. The sensor comprises the following components:

- 3 LilyPad Accelerometer ADXL335 sensing unit,
- 2 LilyPad Arduino 328 Main Board as the central node read sensor data from the 3 accelerometer separately,
- a small and inconspicuous LilyPad Power Supply with input battery from 1.2v-5v,
- a Bluetooth Mate Silver module for wireless communication between the jacket and smartphone,
- LilyPad Vibe Board embedded closely to the accelerometer providing vibration feedback.

Figure 2. System overview.

3.2 Garment design

Figure 3. Prototype of smart rehabilitation garment.

The garment, as shown in Figure 3, is designed in "front" and "back" parts for ensuring the accurate sensor position and measurement. Based on the adjustable design on shoulder and wrists, the garment can fit multiple sizes of people and keeps the sensors close to users' body and at the right location.

3.3 Conductive textiles integration

Conductive textiles in health care garment applications show a great potential, can help users who wear them feel more free and monitoring posture all day for home-based rehabilitation. In this system, a conductive network was applied to enhance the aesthetics of the design without adding the original resistances. We designed conductive fabric pattern for the removable design of wearable sensor and conductive path for the connection between the electronic modules, shown in Figure 4 and Figure 5. The sensors can connect to the garment by attached snaps.

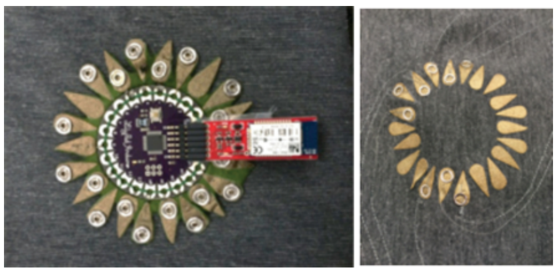

Figure 4. Conductive fabric pattern for Lilypad Arduino.

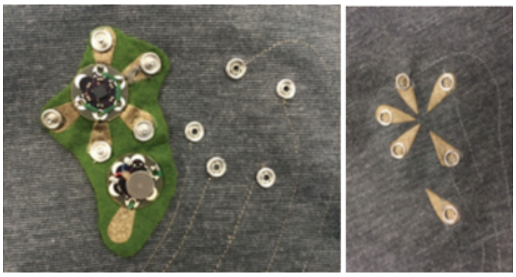

Figure 5. Conductive fabric pattern for Accelerometers.

Furthermore, as the cut pieces are small and needs to be exact match, laser cutter is effective for this process.

4. FUTURE WORK

In the future we will develop the system in following steps:

- The implementation of data processing, signal analysis like signal filter to pre-process data and multi-channel data fusion and will be conducted to eliminate noise from the system.
- The software interface design, enhancing the graphical feedback and providing historical training datasheet.
- Carrying on preliminary evaluation of the garment.

5. CONCLUSION

We set out to design a garment as a platform for arm-hand rehabilitation research. We have proposed a design of the smart rehabilitation garment system, providing feedback of compensation movement to improve users' correct execution of exercise. The integration of smart textiles design to wearable objects contributes to implement the reliable and comfortable monitoring system. The system can be used in different context and training approaches and the adjustable design ensures the sensors staying in right positions. Due to the modular and cost-effective design, the system has a good potential that achieves both accuracy and comfort.

6. ACKNOWLEDGMENTS

We thank Annick A.A. Timmermans for her guidance on the sensing position. We also thank the Chinese Scholarship Council for supporting the research.

7. REFERENCES

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