Motion sensitive clothing

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Abstract. Pervasive systems have a vast potential to provide novel assistive solutions, in particular in personalized health and sports applications. Recent research has been directed to develop smart monitoring garments with integrated sensors and processing functionalities to address these fields. It was found that clothing is an ideal platform for sensing and recognizing activities in natural out-of-lab settings. This paper discusses approaches to activity monitoring using smart garments and introduces the smart shirt (SMASH), a prototyping platform for quick exploration of options and challenges in development of convenient sensing garments. We discuss the primary challenge to obtain casual fitting cloths that can robustly identify activities at the same time.

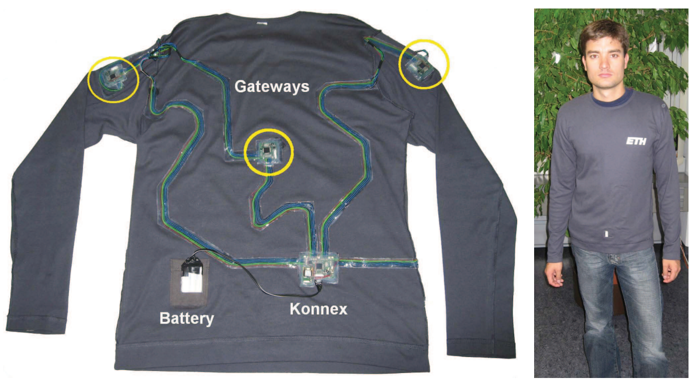
Key words: Smart Clothing, Posture Monitoring, SMASH

1 Introduction

The integration of sensors into garments leverages advantages of clothing with respect to comfort for the wearer and - due to large clothing surface area - freedom in number and positioning of sensors. Smart sensing garments enable new on-body assistance solutions, including personal sport coaches, or training assistants in movement rehabilitation. Another field of application for motion sensitive clothing is monitoring of body postures in children for early prevention of back pain. Classic posture measurement was limited to stationary environments, equipped with expensive optical motion capture installations and extensive video processing needs. Smart garments, in contrast, can be worn in everyday life situations, outside laboratories - anywhere and anytime. The challenge for a broad adoption of smart garments is to integrate effective monitoring functions, while preserving characteristic properties including touch and feel experience, and convenient fitting.

2 Motion sensitive clothing

Portable posture motion sensing systems have been investigated using various integration techniques and sensor modalities. The Backmanager prototype, represents one example of a tight-fitting posture monitoring garment [1]. It uses textile-integrated strain sensors to measure elongation pattern at selected locations inside the garment that are caused by body movements and postures. Following the assumption that different body-postures result in specific strain patterns, it can be utilized to discriminate body postures after an initial training phase. Sensing garments such as the Backmanager are a vital tool for movement and posture monitoring. While this setup is feasible for expert-supervised evaluations, the tight-fitting garment lacks wearer comfort. With tight-fitting garments it can become completely unfeasible for handicapped or elderly individuals to attire themselves. In movement rehabilitation training of patients with limited motor functions, tight-fitting systems have a similarly limited application. Here, systems for individual training at home are sought that can be continuously worn for a whole day. While conveniently fitting smart garments can address these requirements, they could record unreliable sensor orientation data, due changes in garment alignment relative to the wearer's skin. To explore the application options and challenges of conveniently fitting smart garments in everyday life situations, we implemented a platform that we call SMASH (SMArt SHirt) [3].



(a) (b)

Fig. 1. (a) Inner side of the SMASH prototyping garment. Several processing units of SMASH are visible: the Konnex and three Gateways (encircled, a fourth Gateway is hidden) [3]. (b) The worn SMASH platform. [3].

3 SMASH prototyping platform

The SMASH prototyping garment consists of a hierarchical hardware architecture that resembles the stack of a activity recognition system. Each hardware layer implements a standard task performed in activity recognition.
Signal level: Sensing Terminals of arbitrary modalities perform sensing and signal processing tasks at the signal layer.
Feature level: Multiple Terminals can be attached to Gateways, which combine sensor information and condense them into feature abstractions.
Recognition level: Features provided by the Gateways are sent to a Konnex unit, which performs pattern recognition tasks and functions as the global system master. Depending on the intended application, the Konnex can provide a

context-aware feedback to the wearer.
The Konnex and Gateway units were unobtrusively integrated to the inner side of a long-sleeve shirt using silicone gel (compare Fig. 1(a)). While preserving convenient fitting at the body, we have found that SMASH can perform sample-wise on-body recognition of postures, which are relevant in shoulder and elbow movement rehabilitation [3]. A particular rehab application that exploits the full potential of SMASH is movement and posture rehabilitation in children [4]. Good postural control promotes movement efficiency and contributes to an overall wellbeing. Inadequate postural habits can lead to back pain in later life. It is particularly critical to train postural control in early stages of life and the developing body to prevent back pain later on. Figure 2(a) depicts a sensing garment based on the SMASH architecture that was developed to monitor spine inclination in children. We equipped garments of different sizes with five acceleration sensor terminals each. The sensors were placed at different locations of the back to evaluate their individual value in determining bad postures. While smart garments on the basis of SMASH can monitor various spine and shoulder-related positions in everyday life, they could moreover be extended to provide immediate feedback. Early diagnosis and interventions can be used to training children in improving their postural behavior and prevent back pain.

(a) (b)

Fig. 2. (a) Sensing garment based on the SMASH architecture used in monitoring spine inclination in children. Five acceleration sensors were attached to the shirts using silicone gel (encircled positions) [4]. (b) Children wearing the garments in their school class. Inapropriate sitting habits could be improved by providing reminders to change the position.

4 Information robustness in casual sensing garments

Robustness in derived information and wearer acceptance are essential, but often contradictory requirements in monitoring garments. Wearer acceptance requires fashionable garments that can be conveniently worn, and easily put on and off. In contrast, information robustness in sensing wearer motion and postures is affected by the “looseness” of a garment. The orientation of garment-integrated sensors is affected by relative movements between sensor and garment. To date, garment strain, wrinkle structure, and the corresponding sensor orientation are not sufficiently understood. Consequently, the impact of fitting on information quality cannot be sufficiently estimated. With the information on orientation errors, their influence in particular garment configurations, wearer fitting, and activities could be estimated. In initial investigations we quantified the influence of body-garment mobility through a *loss of accuracy* metric [5]. We developed an approach to simulate the garment-based posture recognition performance with the help of orientation error statistics [2]. These statistics were derived in studies using a SMASH system of constant size with participants that fitted the garment differently. Our preliminary results indicated that the recognition performance can be estimated for a particular garment fitting, posture set, sensor location and modality. Those investigations are first steps to understand the tradeoff between convenient fitting and system performance in sensing garments.

Conclusion

In this paper we outlined two approaches to motion sensitive garments. The first approach utilized strain sensitive sensors for measuring elongation patterns in tight-fitting clothes. While this approach is beneficial for supervised applications, it severely limits wearing comfort, which prevents day-long recordings. The second approach is based on a convenient smart garment prototyping platform, called SMASH. SMASH allows to attach inertial sensors on arbitrary locations for measuring upper-body postures, and to provide feedback to the wearer. As one relevant example application, we utilized the SMASH architecture to measure back inclination in children. SMASH has proven to be a valuable prototyping platform for analyzing design parameters of convenient sensing garments. These garments can be utilized for day-long monitoring in natural, everyday life settings, in contrast to tight-fitting cloths. SMASH has moreover shown to provide valuable information on the effect of sensor locations and modalities. The system continues to deliver valuable insights to find a balance between information robustness and convenient fitting.

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