FabricID: Using Smart Textiles to Access Wearable Devices

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Abstract
Wearable devices like smart watches or eye-wear computers are storing a myriad of personal information. Today, wearable devices support input techniques such as speech and gesture input. These user input methods, however, are not well suited for authentication. With the development of smart textiles the design space for interaction for small smart devices can be increased. In this paper, we present the concept of *FabricID* a system which identifies users’ hand-prints with a smart textile integrated into the sleeve of the user. To evaluate our concept, we recorded hand-prints of 16 users. We classified all recorded hand-prints and received an identification rate of 82.5% for all 16 users and on average 93.62% for groups of 4 users.

Author Keywords
Smart textiles; authentication; identification; wearable computing.

ACM Classification Keywords
K.6.5 [Computing Milieux: Security and Protection]: Authentication

Introduction

Wearable devices such as smart watches or eye-wear computers store personal information of the users such as access to social media, bank accounts, or private messages. In contrast to mobile phones, these devices offer a limited set of input methods which can be used for identifying and authenticating the user making this process cumbersome. Thus, entering passwords, pins, or lock-patterns is challenging. Furthermore, while the user enters the secret, an attacker can get knowledge of it by shoulder-surfing [1]. One way of tackling this challenge is using biometrics to identify and authenticate users. Different characteristics of the human are unique enough to be used as a biometric. Various systems have been proposed which use biometric characteristics to identify users such as fingerprints, the iris, veins, and the voice [7]. For example, Holz et al. identified the user by detecting their fingerprints during their interaction with a touch-screen [5]. Furthermore, Pohl et al. developed a button that identifies the users by their clicking behaviors [10]. For wearable devices, research explored exploiting touch screens for detecting shapes of users‘ body parts such as ears or fists [6] or identifying users based on their head geometry [13].

At the same time, smart textiles gain more and more importance. Traditional textiles get substituted by their smart counterparts allowing users to utilize their garments for input (e.g., touch enabled textiles [9, 14] or bend and stretch sensors [9, 15]) as well as output (e.g., textile displays [8, 12]). Even though the spatial resolution of textile touch screens is reduced compared to nowadays touch screens used for mobile phones, the general capability is similar [2, 4]. Direct touch input, strokes, and multi-touch gestures can be used to control wearable devices compensating their drawbacks of limited input methods [11].

Figure 1: The *FabricID* system uses hand-prints to identify users.

In this work, we propose extending this technology to identify or authenticate users on wearable devices. Similar to the work by Tartz et al. [16] and Guo et al. [3] who propose using touch-screens on mobile phones, we propose using touch sensitive textiles for identifying users based on their hand-print. We developed a prototypical system realizing this approach called *FabricID*. The system identifies the user’s hand as soon as the user places his or her hand on it (cf., Figure 1). We evaluated the concept *FabricID* by recording the hand-prints of 16 users and received a identification rate of $82.5\ \%$.

The FabricID

The *FabricID* consists of a touch-sensitive fabric integrated in the sleeves of the user‘s clothing (cf., Figure 1). It is capable of differentiating the users’ hand-prints by measuring the pressure distribution as soon as the user placed a hand on the *FabricID*. The pressure distribution depends mainly on the user’s hand but also on the arm at which the textile is placed. This information can then be used for identifying or authenticating users on wearable devices such as smart watches or eye-wear computers.

Hardware Setup
The *FabricID* prototype uses a touch sensitive fabric similar to the one Zhou et al. [18] integrated into the sleeve of a garment (cf., Figure 2). The fabric itself consists of three layers and has a dimension of 16cm x 16cm. On the outside layers, groups of 32 parallel stripe electrodes of 3mm width with 2mm spacing between two electrodes are attached to the inner sides of the fabric. Both outside layers are placed perpendicular to each other. A force sensitive fabric is placed between these two layers which reduces the resistance based on applied vertical pressure. Each crossing of two stripe electrodes acts as a resistive sensor and can individually be accessed. Thus, we can measure the resistance at all 32 by 32 overlaps (i.e., the system consists of 1024 pressure sensors). The prototype of *FabricID* is fixed with Velcro tape around the forearm of the user and is connected via cables to a small processing board with 50Hz sampling rate (cf., Figure 2 – bottom left). The processing board uses a wired and wireless connection to forwards the sensed information in real time.

User Identification
We identified users based on the 1024 pressure sensors values as input. The feature detection consists of two different kind of features. The first feature is the distribution of the applied pressure. In a first step, we filtered all values below a threshold of 5% of the maximum value. Then, we grouped each pressure sensor into one of 70 bins based on the measured pressure value. For the second feature we used the size of the hands. Thus, we calculated the hands width and height. The distances are calculated between the leftmost and rightmost (i.e., width) as well as the topmost and bottommost (i.e., height) sensor exceeding the threshold. The 70 bins and the distances serve as features for a lightweight 5NN classifier. As a distance measure, we used the Euclidean distance between the size of the bins

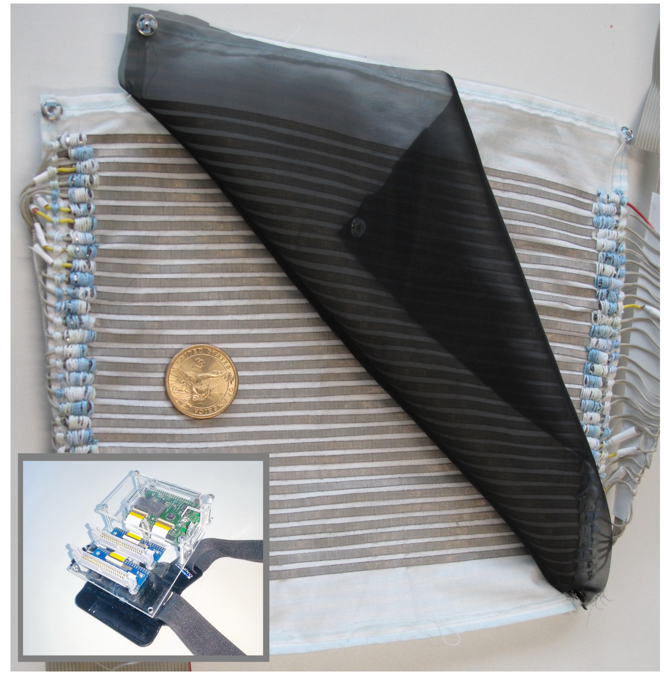
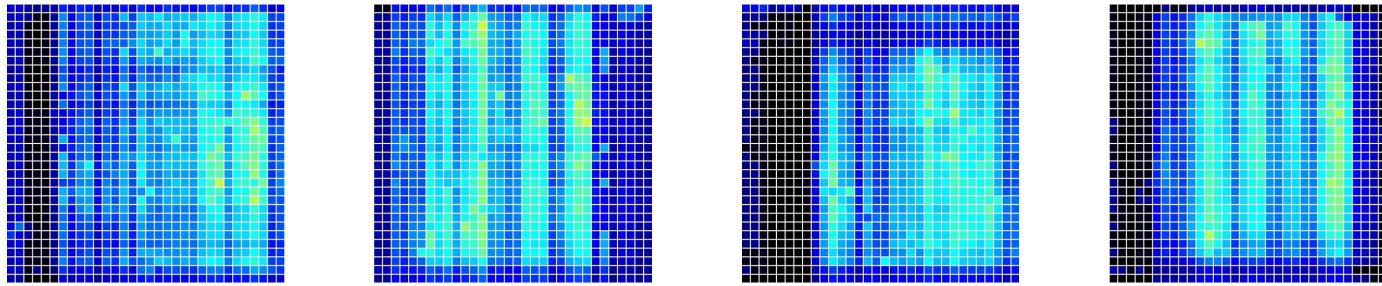


Figure 2: Used touch-sensitive fabric and used processing board (bottom left)

and the distances. We weighted the width and height with a factor of 20 to compensate the importance of this measure compared to the 70 bins.

Data Collection
To evaluate the *FabricID* we conducted a lab study to record hand print data.

Participant and Procedure
We recorded the data of 16 participants (4 female) aged between 21 and 40 years ($M = 28.0$, $SD = 5.32$). After



(a) P10 **(b)** P12 **(c)** P13 **(d)** P14

Figure 3: Example hand-prints of 4 participants of the data recording.

arriving at the lab, participants first signed an informed consent form and filled in a demographic questionnaire. We explained the general idea behind our *FabricID* concept and the procedure of the data recording session. Then, we placed the touch-sensitive fabric with Velcro tape on the left forearm of the participants. The participants were sitting while recording the data and were asked to lift their arm so that the fabric does not contact the desk. We explained them the aspired form for the hand print. All fingers should touch the smart fabric and the index finger, the middle finger, the ring finger and the pinkie should be rest to each other and thumb should be straddled. The aspired form of the hand is also shown in Figure 1. We recorded for every participant 30 hand-prints using a USB connection between *FabricID* and a recording computer (cf., Figure 3). To avoid sequence effects, we asked the participants to move their fingers and the arms after each recording.

Analysis
We analyzed the recorded data using a cross-validation approach. For each fold, we excluded a single recording for a single participant (i.e., the person to be identified). We compared this recording with the remaining 29 recordings of the same participant as well as all the recordings from the remaining 15 participants. In total, 396 of 480 hand-prints (82.50%) were classified correctly.

In addition to that, we analyzed small sub-groups of 4 users. This simulates a working scenario or a family scenario in which an eye-wear computer is shared among the members of a company or the family. We therefore calculated the identification rate for each possible subgroup of 4 users using the same approach as before. Averaged over all 1820 subgroups, we achieve an identification rate of 93.62%, $SD = 4.24$).

Application Scenarios
We envision two main application scenarios in which *FabricID* can support users of mobile and wearable devices.

Protecting Private Content
The content stored on a smart watch are highly personal and should not be accessible for others. We propose using *FabricID* in combination with a smart watch. The users simply grab their arm to unlocks their smart watches.

Identifying user of Eyewear Computer
Eyewear computers are mainly designed as a personal devices used by a single user. However, these devices are also used for applications in which many users share these devices such as in a hospital for surgeries or for training in an industrial setting. Users have their own settings for the eyewear computer which needs to be manually selected at the start. *FabricID* eases up this process by simply grabbing the lower arm.

Discussion and Limitations

While an identification rate of 82.5% leaves room for improvements, we believe that the identification rate can be increased. For evaluating our system, we recorded data of 16 users. We believe that, for example, in an industrial setting, an eyewear computer could be shared with a similar number of users. However, for a family setting, for example, a family of 4 people would result in a higher identification rate ($M = 93.62\%, SD = 4.24$). Additionally, in our first exploration of the *FabricID* concept, we applied a simple nearest neighbor approach. A more sophisticated algorithms and features can further increase the identification rate.

We used for our prototype a resistive sensor with a resolution of 32×32 sensing points. Therefore, we can measure only inaccurate hand sizes. Additionally, because of the factors of the flexible cloth, the geometry of the forearm, and the users' skin, we have no rigid and planar surface for constant measurements of the applied pressure. This might be compensated by a higher spatial resolution.

In a real world scenario, this approach might face further challenges. For example, the textile might get wrinkled which can reduce the detection accuracy.

This work investigates the concept of *FabricID*, which uses the users' hand-prints for authentication. We used smart fabric worn by the authenticating users themselves. In addition to that use case, the approach might also be usable in cases in which two collocated users need to authenticate themselves to each other. In this case, both users could grab the forearm of the other person. A further potential use case could be shared clothing. Factory workers wearing specific protective clothing could use this method also for authenticating them to specific accessory.

Further, we also envision that the authentication with the users' hand-prints can be extended to other sensors. This could include thermal cameras utilizing the thermal hand-print or other materials such as touch-sensitive skin tattoos [17].

Conclusion

In this paper, we proposed the concept of *FabricID*, a systems which uses the users' hand-prints for identification on wearable devices. We used a touch-sensitive fabric on the sleeve of the user to detect the users‘ hand-prints. In a first exploration of the concept, we achieved an accuracy of 82.5% for a group of 16 and $M = 93.62\%$ for a group of 4 users showing the general feasibility of the approach. In the study we recorded hand print data of the participants, calculated features of the single hand prints and classified them. Although we used for the system a resistive sensor with a resolution of 32×32, we achieved a classification rate of 82.5%.

In the future, we will explore how a larger spatial resolution of the sensor will increase the classification accuracy. Further, we will explore the suitability of fabric-based multi-sensing technologies for authentication and identification [2].

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