SkinMotion: What does Skin Movement Tell Us?

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Abstract

With the increasing popularity of wearable computing, emerging techniques allow novel interaction modalities to be transferred from portable devices to the human body itself. One promising approach is to appropriate the skin for input interface. While researches explore the potential of using the skin as an input surface, we show an alternative interaction modality - *SkinMotion*. *SkinMotion* reconstructs human motions from skin-stretching movements. In this workshop, we discuss the potential applications of *SkinMotion*. In addition, we explore one specific instance – finger motion detection using the skin movement on the dorsum of the hand. Results show that *SkinMotion* can achieve 5.84° estimate error for proximal phalanx flexion on average. We expect *SkinMotion* to open new possibilities for skin-based interactions and to extend new boundaries of on-body technologies.

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Introduction

Significant computational resources and lower power consumption allow electronic devices to be more wearable and ubiquitous. As such, there is growing research interest in novel human-computer interaction modalities that go beyond the traditional input strategies such as keyboard, mouse and touch screen. However, the limited interaction space (e.g., diminutive screen) damages user experience and prevents wearable devices from realizing their full potential.

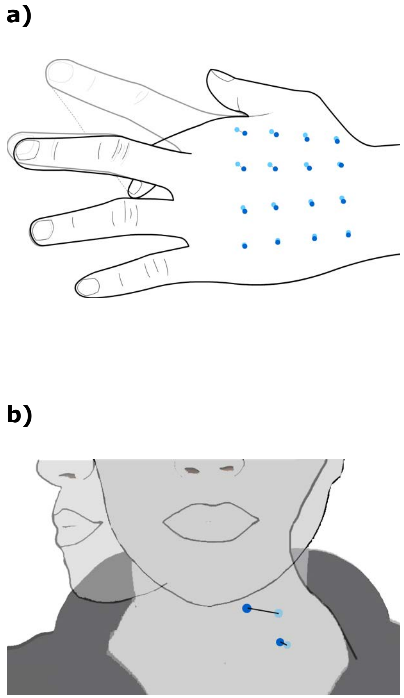

Figure 1: The body parts *SkinMotion* detects. a) shows the finger movement detection using the skin stretch on the dorsum of the hand. b) shows the head position reconstruction using the skin movement on the neck.

One promising solution is to appropriate the human body itself for new interaction modalities. Specifically, researchers realized on-skin interactions appropriating the skin surface as input platform [7, 8, 9, 17].

Beside extending our skin surface into interaction surface, our skin can also carry other interaction modalities. In this workshop, we present *SkinMotion* to explore new on-skin sensing techniques for human motion reconstruction. We expect *SkinMotion* to open new discussions about on-skin technologies and to expand new boundaries for on-body interaction.

SkinMotion

It is well known that human motion is lead by the movement of joined bones and muscles. This will cause the skin to stretch and different human motions cause different skin movement patterns [14]. Hence, it is possible to reconstruct the human motion from the skin's stretching patterns. Researchers have fully explored this approach in facial recognition for detecting user's facial expression [6]. However, this method has not been fully explored for other interaction interface. Therefore, we will present the value of *SkinMotion* in this workshop and suggest a few applications that can be supported by *SkinMotion*.

- **Air-typing in VR/AR systems.** *SkinMotion* measures the skin stretch on the dorsum of the hand to detect the position and movement of fingers as shown in Figure 1a. We can thus recover the finger movement into digital world and users can perform air-typing to input text in VR or AR systems.

- **Hand gesture recognition.** Besides the air-typing application, users can also perform finger/hand gestures to control media play or other applications using *SkinMotion*.

- **Head position detection.** *SkinMotion* can be appropriated for fitness and health applications. For instance, it can detect the skin stretch on the neck to recover the position and movement of user's head as shown in Figure 1b. As such, wearable devices can be used to detect users' sitting postures and help keeping users' spine healthy. They can also detect whether the users nap while driving the car.

Finger Movement Reconstruction

In this section, we explore the feasibility of using *SkinMotion* for finger position detection. Researchers have sought to be able to accurately detect and record the movement of human fingers. Transferring this modality into the digital world has thus become a major focus in the HCI community.

Many of the technologies that exist to record finger movement have narrowly focused on the fingers themselves. Data glove [5] can detect the hand pose accurately with estimate error of 5°. However, the data glove's accuracy comes at the expense of comfort and convenience. Other solutions use commercial depth cameras [16], wrist-worn cameras [11, 12], head-worn cameras [3]. Unfortunately, camera-based systems suffer from occlusion issues, high power consumption, and light limitations. To overcome the problems inherent in recording finger movement directly, researchers use sensing techniques with different signals on related areas such as the wrist. These sensing techniques include capacitance-sensing [13], electromyography (EMG) [15], and pressure sensing [4]. However, these signals are noisy and can only

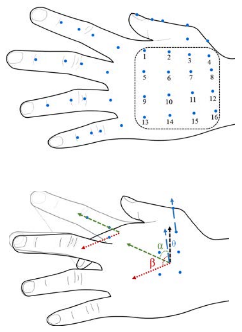

Figure 2: The marker layout and the method of calculating flexion of each finger. (The normal vector is represented by the black arrow, the flexion angle of the thumb by θ and the flexion angle of the index finger by α, β)

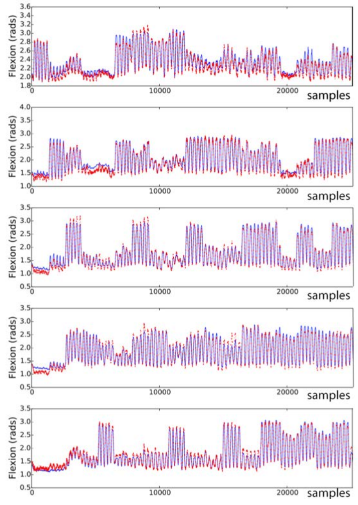

Figure 3: The linear regression results of one randomly chosen participant. The red line is the estimate flexion and the blue line is the real flexion for each finger.

support a small discrete set of hand gestures. The main challenge faced by researchers still remains the ability to recover finger movement with precision and robustness.

Experiment Design

We used the motion tracking system *OptiTrack* [1] to evaluate the feasibility of *skinMotion*. The official software *Motive* runs on a personal computer (Intel i7-4765T@2.0GHz, 8G RAM). The data was processed offline. A computer screen, positioned in front of the participant, gives instructions of what the gesture the participant should perform. We recruited 12 participants (6 females, 6 males) ranging in age from 20 to 34 (M = 26.67, SD = 3.78) in this experiment.We designed a full set of finger gestures including single finger and multiple fingers flexion. There are two blocks in this experiment. We explored the amount of training set on the performance by randomly selecting specific amounts of training data from 1 training set to 5 training sets from the first block. Using the trained linear regression model, we estimate the finger flexion on the test set (the second block).

Result

Finger flexion range and skin stretch distance. The finger flexion range and skin stretch distance of each finger are shown in Table 1.

Estimate performance. On average, the estimate error reaches to 3.77◦ for the thumb, 5.87◦ for the index finger, 6.43◦ for the middle finger, 6.9◦ for the ring 4.5 finger and 6.22◦ for the little finger. *SkinMotion* has low training burden with just 4.63% accuracy increase when use more than one training data. The linear regression results of one randomly chosen participant is shown in Figure 3. This indicates the high performance of *SkinMotion* in finger flexion prediction compared with the 5° estimate error of data glove.

	Flexion Range Mean (std)	**Stretch Distance Mean (std)**
Thumb	59.47°(10.41°)	1.52 (0.63) mm
Index Finger	103.84°(6.19°)	2.72 (1.23) mm
Middle Finger	112.35° (7.71°)	2.34 (1.44) mm
Ring Finger	115.00° (8.72°)	1.88 (0.96) mm
Little Finger	121.35° (13.71°)	2.77 (1.12) mm

Table 1: The flexion range and skin stretch distance on the dorsum of the hand of each finger.

Research Area and Topic

Personally, my research interests focus on eyes-free and on-body interaction for mobile or wearable computing devices.

Discussion

We have proposed a new on-skin approach for motion reconstruction using the related skin stretch, called *skinMotion*. Besides, we demonstrated that *skinMotion* could be used as a potential wearable interface. In detail, we used *OptiTrack* to evaluate the feasibility of finger motion tracking by sensing skin tension. In addition, it can achieve an estimate error of 5.84° on average. However, there are several issues I want to discuss in the workshop.

Lin et. al. proposed a solution for skin movement detection using the strain gauge sensors [10]. It supports the recognition of discrete set of hand gestures. However, the sensors cannot fully recover the skin stretch due to the limitation of the stretch range

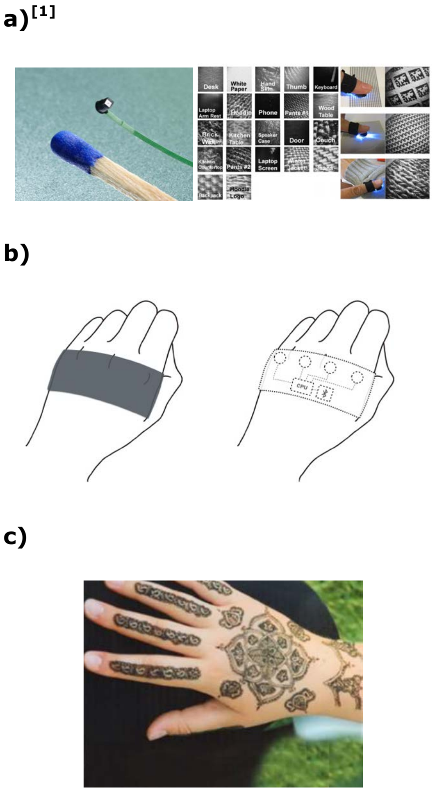

Figure 4: a) Potential sensing techniques and b) wearable device forms. c) wearable sensors based on conductive polymers or inks.

[1] Xing-Dong Yang et. al. Magic Finger: Always-Available Input through Finger Instrumentation. UIST'12 147 – 156.

(~0.5 mm). Hence we need to explore more suitable sensing approaches that consider stretch range, accuracy and sensitivity. In addition, the wearable device worn on human body should be comfortable.

One possible approach is to attach micro camera (Naneye, provided by AWAIBA [2]) with macro lens on the skin. This can detect the skin texture change to reconstruct the motion of the related joint. The wearable device can be made as a hand band.

Besides, we are attempting to design suitable stretch sensors based on conductive polymers or inks. In this way, we can print or attach the sensors on the skin in the form of the tattoo. However, we have not found the accurate sensing configuration with a large stretch range (at least 2 mm).

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