Hand Gesture and On-body Touch Recognition by Active Acoustic Sensing throughout the Human Body

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ABSTRACT
In this paper, we present a novel acoustic sensing technique that recognizes two convenient input actions: hand gestures and on-body touch. We achieved them by observing the frequency spectrum of the wave propagated in the body, around the periphery of the wrist. Our approach can recognize hand gestures and on-body touch concurrently in real-time and is expected to obtain rich input variations by combining them. We conducted a user study that showed classification accuracy of 97%, 96%, and 97% for hand gestures, touches on the forearm, and touches on the back of the hand.

Author Keywords
Hand gestures; on-body touch; combined input; acoustic sensing; machine learning.

ACM Classification Keywords
H.5.2. User interfaces: Input devices and strategies.

INTRODUCTION
The human body is a significant interaction platform for controlling wearable devices and smart furniture, which provide specific feedback on the basis of the tactile sense of the body itself. In research of the body as an interface, there are roughly two kinds of approaches: recognizing hand gestures and recognizing on-body touch. However, most preceding works took up either one or the other. Our goal of this research is recognizing both hand gestures and on-body touch concurrently. To do this, we focused on an acoustic sensing technique, observing the ultrasound wave propagated in the body. By using a similar acoustic method, Okawa et al. detected a finger gesture on the basis of its joint angle [4], and Mujibiya et al. enabled 1D continuous touch on the body [1]. Unlike Mujibiya et al.'s work, we recognize touch only on a discrete pre-learned position of the body. Our work is inferior in this respect, but it has great potential for rich input variation by combining hand gestures and on-body touch.

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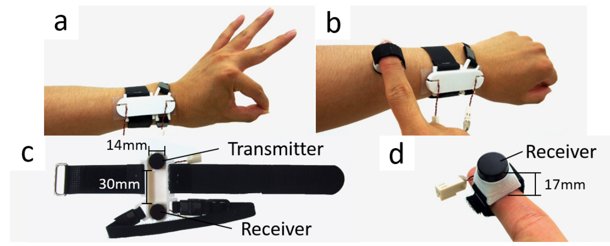

Figure 1. Appearance of the prototype: a) hand gesture recognition, b) touch recognition (on the forearm), c) general view of the wristband, d) and the ring.

PROTOTYPE
Our system recognizes hand gestures and on-body touch by analyzing the ultrasound wave propagated through the body. The prototype device consists of a wristband and a ring and has drop-proof aluminum housing transducers (Figure 1).

Active Acoustic Sensing throughout the Human Body, Especially from Forearm to Hand
In our implementation, we mount a transmitter on the wrist perpendicularly. Then, we drive the transmitter by a specific ultrasound signal and apply the oscillation to the human body actively. The oscillation propagates from the wrist, and we receive the wave by mounting receivers on around the periphery of the wrist. By observing the frequency spectrum of the wave propagated in the body, we can sense the conditions of the body as a medium that has relation to its transfer characteristics, such as the posture of the hand and the position of the receivers.

Hand Gesture Recognition
For recognizing hand gestures, we use a receiver mounted near the styloid process of the radius, which is about 30mm away from a transmitter on the wrist (Figure 1a and c). A user wears a wristband with the pair of transducers on one side of the wrist like he/she wears an ordinary wristwatch. To prevent slipping the transducers' position, we put a 1-mm-thick silicon rubber sheet between a sensor case and the wrist. We adopted a hand gesture set that has 8 hand postures (Figure 2a). The frequency spectrum of the received wave changes with moving of joints and muscles, which attend on the hand gesture. (Figure 3a).

Touch Recognition on Forearm and Back of the Hand
For recognizing on-body touch, the user touches his/her own body with mounting a receiver worn as a ring on the opposite hand from the band-wearing wrist (Figure 1b and d). We adopted two touch sets, each of which has 9 touch positions (3 × 3 dot matrix with 2cm intervals), on the fore-

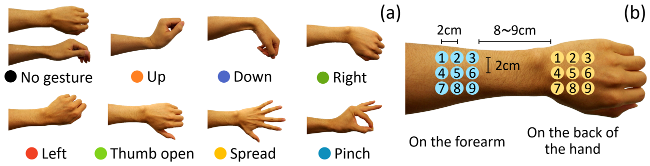

Figure 2. Hand gesture set (a) and two touch sets: on the forearm and on the back of the hand (b).

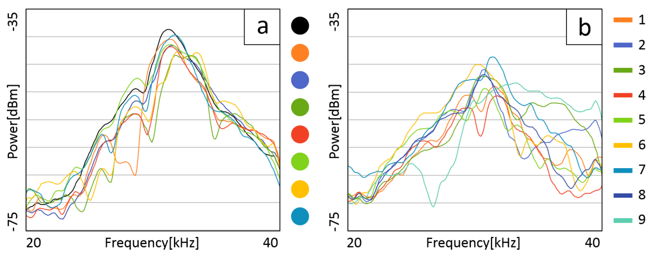

Figure 3. Alternation of power spectrums by hand gesture (a) and touch on the forearm (b).

arm and on the back of the hand, respectively (Figure 2b). The frequency spectrum of the received wave changes with the position of the receiver, due to the difference in distance and internal tissues of the pathway. Figure 3b shows the forearm case.

Implementation

We used Murata MA40MF14-0B transducers and drove them by using a USB audio interface, Roland OCTA-CAPTURE. For signal processing, we used the MATLAB. The transmitter was driven by the swept frequency signal, whose frequency increased linearly from 20kHz to 40kHz in about 30ms at a 96kHz sampling rate, and the driving voltage was about 10mVrms. Then, an ultrasound wave 69.7dBSPL on average was applied to the body. This output was lower than the safe levels of SPL in this sweep range [3]. Each received wave was amplified by Toshiba TA7252AP and analyzed by FFT, which was a common sampling rate and 5120-point hann window. The total power consumption of the amplifier is about 0.54W. For classifications, we collected 100 features from the frequency spectrum at a 200Hz interval in the sweep range. We used a SVM implementation provided by the LIBSVM in the MATLAB (RBF kernel with default parameters) [2]. All processing for hand gestures and touch (FFT + SVM classifier) was able to run concurrently.

EVALUATION

We evaluated accuracy for each hand gesture and touch. We recruited 4 participants (1 female) with a mean age of 23, all right handed. They wore the wristband on their left forearm and put the arm in front of their chest. First, we collected data of the hand gestures and then the two touches on the forearm and the back of the hand. For a single round of the data collection, we designated once all actions from 8 hand gestures or 10 touches ('No touch' + 9 positions, draw the matrix on the skin with a pen) in randomized order and collected 10 data points from each action. We made the participants put their left forearm down during intervals between rounds and collected 10 rounds in total. During the two touches, the participants kept their left hand posture as 'No gesture.' This procedure resulted in three datasets: 3200 data points in the hand gesture set, and 4000 data points in each of the two touch sets.

On each dataset, we trained on nine rounds and then tested on the other round in all combinations, and averaged these results per user. As results, we achieved a mean accuracy of 97.0% (SD = 0.80%) for the hand gestures, 95.7% (SD = 2.43%) for the touch on the forearm, and 97.3% (SD = 2.94%) for the touch on the back of the hand.

Accuracy of Touch Input Combined With Hand Gesture

For recognizing the touch input combined with the specific hand gesture (except 'No gesture'), our system needs additional touch datasets in which the user keeps the left hand in the specific gesture during the data collection. The system classifies these touches by changing their SVM model by adjusting to the classification results of the gesture. Our preliminary study suggested that touches on the forearm tend to differ little in terms of accuracy regardless of the left-hand gesture. Thus, when the touch on the forearm is combined with a hand gesture, the accuracy can be guessed to become close to the product of individual accuracy of the hand gesture and the touch with 'No gesture'.

POTENTIAL APPLICATION

Applying the above-described input technologies, we can realize various types of interaction methods. In this paper, we propose a new touch input, which can change the output of the touch by hand gesture. We show two contents of this input. 1) *Keypad*: the user can change three input modes of the on-body keypad (two alphabet modes and one numeric mode) by hand gestures: No gesture, Spread, and Thumb open (Figure 4a, b, and c). 2) *Controller having plural targets*: The user can control various objects by on-body touch by choosing the operational target by hand gestures (Figure 4d and e).

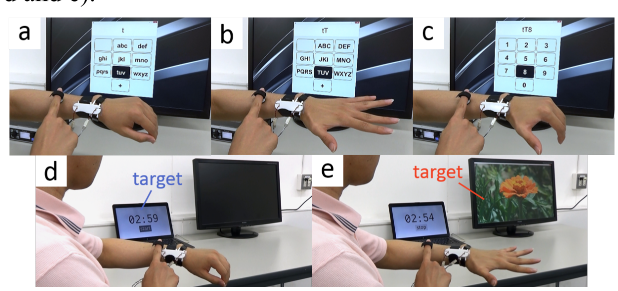

Figure 4. ***Keypad*** **of a) lowercase mode, b) uppercase mode, and c) numeric mode; and** ***Controller*** **targets d) notebook PC (timer application) and e) display.**

CONCLUSION

We recognized hand gestures and on-body touch concurrently in real-time by active acoustic sensing. We will evaluate the combined input as future work.

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REFERENCES

1. Adiyan Mujibiya, Xiang Cao, Desney S. Tan, Dan Morris, Shwetak N. Patel, and Jun Rekimoto. The Sound of Touch: On-body Touch and Gesture Sensing Based on Transdermal Ultrasound Propagation. *In Proc. ITS '13*, 189-198, 2013.
2. Chih-Chung Chang, and Chih-Jen Lin. LIBSVM: A Library for Support Vector Machines. Available online at: https://www.csie.ntu.edu.tw/~cjlin/libsvm/. Accessed at July 4th, 2016.
3. Non-Ionizing Radiation Section Bureau of Radiation and Medical Devices Department of National Health and Welfare. Guidelines for the Safe Use of Ultrasound: Part II - Industrial and Commercial Applications. Available online at: http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/safety-code_24-securite/index-eng.php. Accessed at July 4th, 2016.
4. Yuya Okawa, and Kentaro Takemura. Haptic-enabled Active Bone-Conducted Sound Sensing. *In Proc. UIST'15*, 87-88, 2015.