A Proposal for MMG-based Hand Gesture Recognition

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ABSTRACT
We propose a novel hand-gesture recognition method based on mechanomyograms (MMGs). Skeletal muscles generate sounds specific to their activity. By recording and analyzing these sounds, MMGs provide means to evaluate the activity. Previous research revealed that specific motions produce specific sounds enabling human motion to be classified based on MMGs. In that research, microphones and accelerometers are often used to record muscle sounds. However, environmental conditions such as noise and human motion itself easily overwhelm such sensors. In this paper, we propose to use piezoelectric-based sensing of MMGs to improve robustness from environmental conditions. The preliminary evaluation shows this method is capable of classifying several hand gestures correctly with high accuracy under certain situations.

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General terms: Human Factor

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INTRODUCTION
Active muscle fibers produce specific sounds. Those sounds are audible at the skin surface. Mechanomyograms (MMGs) are signal recordings used to analyze those sounds and to evaluate muscle activity. In addition to observing muscle activity, MMGs have been used to discern human behaviors [3, 5]. Accelerometers and microphones are often used for MMG recordings [4]. Such sensors are quite simple and therefore have the potential to be used as human computer interfaces. However, microphones are easily overcome by environmental noise whereas accelerometers cannot distinguish between target muscle oscillations and other human motion. Therefore, these conventional sensors are not appropriate when considering MMGs for purposes of interfacing computers with humans. When skeletal muscle fibers expand and contract laterally to generate forces, pressure waves occur that produce lateral mechanical oscillations of the muscle fibers [2]. To observe such oscillations, we propose to use piezo-electric elements, small and thin enough to be placed on human skin. Furthermore, acoustic environmental noise and human motion do not affect the monitoring of these oscillations. In this paper, we describe the details of the proposed method and experimental results to confirm the practicality of the proposed method.

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RELATED WORK
Much research has been done on using hand gesture recognition in portable or wearable configurations. Bailly et al. developed a wearable hand gesture recognition system using a depth sensor mounted on shoes. This sensor is directed upward to monitor hand gestures [1]. However, this configuration encumbers the user's actions. Using MMGs resolves this problem. Xie et al. proposed a motion classification method using MMGs [6], where they used accelerometers to measure muscle activity. As discussed above, when using accelerometers, human motion itself affects recordings. Our proposal requires users to wear piezoelectric elements that are capable of distinguishing muscle activity from human motion. Furthermore, being thin and small, the wearer's daily activity is unhindered.

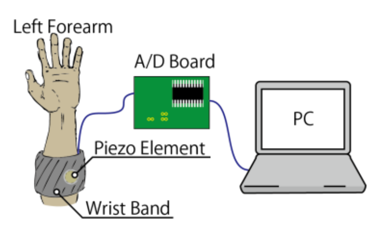

Figure 1: A piezo-based MMG setup

A PIEZO-BASED MMG SETUP AND HAND GESTURE RECOGNITION METHOD
A piezo-electric element is placed on a wristband worn by participants on the medial side of the left forearm (see Figure1). Voltage variations from the piezo-electric element are recorded by PC. A typical result, presented in Figure 2,

shows four overlaid signals recorded during bending and stretching of the index finger. These signals are stable and quite clear.

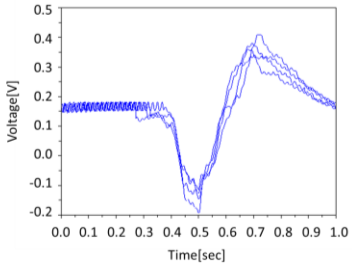

Figure 2: Four typical overlaid MMG signals observed during bending and stretching of the index finger.

HAND GESTURE RECOGNITION EXPERIMENTS

To recognize hand gesture, we simply use a cross-correlation function. First, we record an initial piezo-based MMG as a template for each gesture of each person. This recording serves as a reference when the specific gesture is performed. Next, we evaluate the cross-correlation coefficient between subsequent MMGs and pre-recordings to determine the gesture. We conducted an experiment to evaluate the hand-gesture recognition capability using piezo-based MMGs. In this experiment, we selected three gestures to be analyzed: bending and stretching of the index and the middle fingers, and grasping the hand. Each participant was required to do each gesture once to generate the personal templates. Then, each participant was required to do the same gestures three more times for data collection. We had five participants (all male, 23–25 years old). This gave 15 piezo-based MMGs with five pre-recorded templates data sets for each gesture. Then, by comparing the cross-correlation coefficients between these, we are able to distinguish each hand gesture. Figure 3 shows a typical example of this procedure. The upper graph shows the raw data of the piezo-based MMGs for each gesture. A colored line shows the raw data of the template for each gesture from a specific participant. The black line shows the "unknown" piezo-based MMG for the same person. The lower graph shows the cross-correlations between the unknown data and templates. The maximum value in the lower graph appears in the red line at around 1.5s. This means that the unknown MMG corresponds to a grasping gesture.

Accuracies for all estimation results, listed in Table 1, are above 80%. Thus, experimental results indicate that piezo-based MMGs analyzed with the cross-correlation function have potential in recognizing hand gestures.

CONCLUSION

In this research, we proposed a novel hand-gesture recognition method based on MMGs and piezo-electric element sensing. The experimental results showed this method has potential to recognize hand gestures. For future work, we seek to improve the accuracy of hand-gesture recognition. In addition, we will be developing a wearable-type hand gesture recognition system based on this method.

Table 1: Results for estimating hand gestures from the cross-correlate function.

Motion	Correct Answer	Accuracy
Index	14	0.933
Middle	14	0.933
Grasp	13	0.867

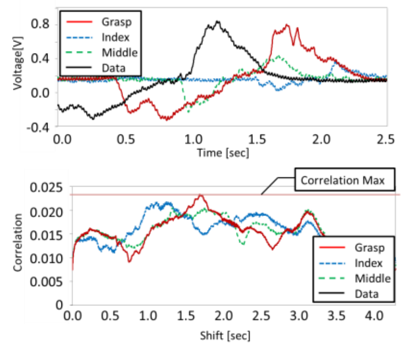

Figure 3: An example for cross-correlation function. In red line (grasp), peak is come out at 1.5s

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