International Journal of Bioelectromagnetism
Vol. 9 No. 2 2007

Finger Motion Recognition by Skin Surface Vibration Patterns

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Abstract

Recently, the development of prosthetic hand systems for hand amputees has attracted wide research interests. Motion-related myoelectric potentials measured from the surface of upper part of forearms were mostly employed to construct the interface between amputees and prostheses. However, finger motions could not be recognized from surface EMG (Electromyogram) signals. the basic idea of this study is to use motion-related surface vibration, to detect independent finger motions without using EMG signals. In this research, a finger tapping experiment used accelerometers was conducted to collect the finger motion related mechanical vibration patterns. The results with a wave form template matching method showed that the finger motion identification is possible by analyzing the vibration patterns.

1. Introduction

It is no exaggeration to say that an upper limb without a hand has barely any function. Recently, the development of prosthetic hand systems has attracted wide research interests. In order to construct the interface between amputees and prostheses, motion-related myoelectric potentials measured from the surface of upper part of forearms were mostly employed, to detect amputees' motion intention, thus, to drive a robotic hand.

It has been reported that using 2-3 channels of surface EMG (Electromyogram) sensors, up to 10 forearm motions can be recognized [1]. However, finger motions, which play a major role in dexterous hand activities, such as precision grasp of small objects, could not be recognized from surface EMG signals, due to the following problems:

1. The EMG signals detected from the skin surface are the superposition of multiple muscle potentials;
2. The electric potentials of the activated muscles, especially, those deep layered muscles, such as extensor indicis, are affected (attenuated and modulated) by various nonlinear elements, such as fat and tissue, before they are summed with other potentials;
3. The finger motions are generally fast, with small range of motion, thus the amplitude of finger-motion-related surface myoelectric potentials is minute and of low S/N ratio.

On the other hand, since the hand and forearm motion related muscles and skeletons are arranged in a very tightly coupled way, the activation of one muscle will cause relative muscles' concomitant movements, which do not result in any additional electric potentials, but indeed produce the mechanical vibration. The concomitant moments thus transfer the mechanical potentials of the voluntary motion of one finger to skin surface. We considered that, the mechanical vibration detected from skin surface is possibly contributive to finger motion detection.

The goal of this research is the identification of finger motion by forearm bio-signals. Accelerometers were employed to detect the finger motion related mechanical vibration from skin surface, and a finger tapping experiment was conducted to collect the vibration patterns, which were then processed using a wave form template matching method [2].

2. Experiment

Ten healthy adult subjects participated in the experiment. Two tri-axial accelerometers (HAAM-325B Hokuriku Electric Industry Co., Ltd.) were used for the experiment. As shown in Fig. 1, one sensor was put on the surface of forearm flexor side (Sensors 1), and another was put on the flexor side (Sensor 2), with both sensors' Z axis perpendicular to the skin surface.

At first, subjects were asked to tap each of 3 fingers (index, middle, ring finger) five times. The data recorded were used to generate wave form templates. Then, subjects were asked to tap their fingers designated by an instructed sequence, which includes

36 times finger instruction randomly chosen from the 3 fingers.

The A/D sampling rate was set to 1600Hz. The sampling and data recording are based on Labview (National Instrument Corp.)

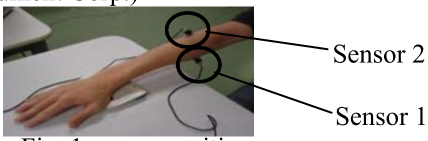

Fig. 1 sensor position

3. Results

Fig. 2 shows typical accelerometer wave forms for 3 finger motions. It is clear that, there was no remarkable difference in amplitude and frequency between the 3 wave forms. That is the reason why a template matching method was then adopted in the following analysis.

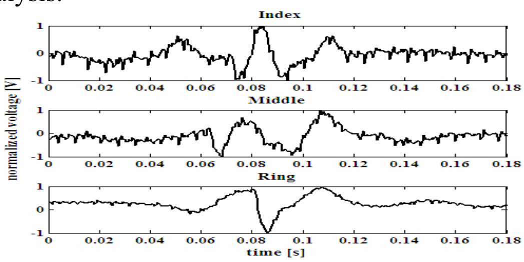

Fig.2 Accelerometer wave forms for 3 finger motions

In order to make the templates, the wave forms of five times tapping were taken out (300 points) from the recorded continuous wave form, and averaged. As a result, with all 6 axes, a template with 3×6 sub-templates, corresponding to 6 accelerometer axes (X1, Y1, Z1 of Sensor1, and X2, Y2, Z2 of Sensor2) for 3 fingers (index, middle, ring finger), was generated. Then, the same points of signals centered at the point with maximal amplitude were cut out to form the identification test samples. A cross correlation coefficient (Eq.1) then was calculated between each test sample and the template. Then finger with the maximal *cr* was decided to be the right finger（Eq. 2).

$$cr_k = \max\left(\frac{\sum_{n=0}^{N-1} x(n) \times template_k(n+\tau)}{\sqrt{\sum_{n=0}^{N-1} |x(n)|^2} \sqrt{\sum_{n=0}^{N-1} |template_k(n)|^2}} \right) \quad (1)$$

N: signal length $x(n)$: unknown pattern
$k = 1$: Index, 2: Middle, 3: Ring

$$Finger = \arg_k \max(cr_k) \quad (2)$$

Fig. 3 shows each axis's correct rate. A point stands for an average value over 10 subjects. A vertical bar denotes the variance of the correct rate.

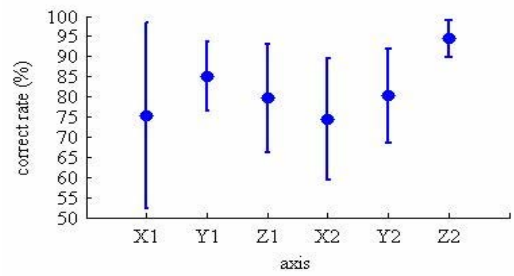

Fig.3 Identification result

4. Discussion

As reflected in Fig. 3, the average correct rates for all 6 axes are relatively high. Even the lowest axis X1, has an average of about 75%. This means that the accelerometer recordings contain sufficient and reproducible information about the finger tapping motion.

Since the axis Z2 has the largest average value and the smallest variance value, this axis should be most suitable for the finger motion detection, which agrees generally to intuitive consideration that the perpendicular direction could receive much more vibration information.

5. Conclusion

In this research, the skin surface mechanical vibration of finger tap motions was investigated. This vibration was measured with the accelerometer and identified using wave form template matching in an off-line way. The results showed that, the finger motion identification is possible by using accelerometers. In the future, hand amputees should be also included in subjects to investigate the feasibility of the approach.

Acknowledgment

This work was supported in part by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research (B), 2007, 19300199

References

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