Human-Computer Interaction - INTERACT'03
M. Rauterberg et al. (Eds.)
Published by IOS Press, (c) IFIP, 2003, pp. 958-961

An EMG-Controlled Graphic Interface Considering Wearability

H. Jeong, J.S. Choi

Electronics and Telecommunications Research Institute,
Yuseong-gu Kajeong-dong 161, Daejeon, Korea
jay@etri.re.kr

Abstract: It is known that graphic interfaces using electromyogram (EMG) generated by wrist motion are a potentially viable for a wearable computer. However, these interface prototypes seem to be not practical because it takes time and effort to set EMG electrodes on scattered positions. For easy-to-wear use, we suggested that the electrodes should be located on a circle around the forearm. Also, we designed the device prototype for attaching EMG electrodes. This device makes it easy to attach the electrodes on a forearm without an adhesive. In order to classify wrist motion, fuzzy min-max neural network was used. The features used in classification of wrist motion were stochastic values such as integral absolute value. After learning the pattern, five wrist motions could be classified well.

Keywords: Electromyogram (EMG), EMG-controlled, wearable input device, graphic interface

1 Introduction

Human Computer Interaction (HCI) technology using a bioelectric signal such as an electromyogram (EMG), an electroencephalogram (EEG) and an electrooculogram (EOG) is considered an alternative to conventional input devices such as a keyboard or a mouse. Among these bioelectric signals, an EMG can be used as a control source for an intuitive and natural HCI because EMGs represent electrical activity of muscles. Also, EMGs can be easily acquired on skin with easy-to-apply surface electrodes.

An EMG is a bioelectric signal generated by muscle use. The amplitude of an EMG can range from 0 to 10 mV (peak-to-peak) and the usable energy of the signal is limited to the 0 to 500 Hz frequency range (Park, 1999). An EMG can be acquired on the skin near to the muscle by differential amplification in order to eliminate the noise signal. An EMG electrode should be placed between a motor point and the tendon insertion and along the longitudinal midline of the muscle (Delsys, 1996).

Graphic interfaces using EMG generated by wrist motion have been studied on the several research (Rosenberg, 1998; Tarng, 1997; Fukuda, 1999). And they have reported that an EMG-controlled graphic interface is a potentially viable graphic interface for a wearable computer. Their researches focused on how to process EMGs in order to distinguish the wrist motion. But they paid no attention to how to attach the electrodes on a forearm. Their interface prototypes seem to be not practical because it takes time and effort to set electrodes on scattered positions. If the EMG-controlled graphic interface could be used practically, studies on how to attach electrodes on forearm should be also considered with studies on how to process the signals.

In this study, we deal with the practical method to attach electrodes on a forearm and the device prototype for practical use in attaching electrodes. Also, the EMG signal processing methods are described for distinguishing the wrist motion.

2 The practical method to attach EMG electrodes on a forearm.

In this section, a practical method to attach electrodes of an EMG-controlled graphic interface on skin is dealt with. At fist, we define wrist motions that can be described as up, down, left, right or click. These wrist motions are shown in Figure 1. At an initial state, the arm should be rested without moving a muscle. The motion for click is defined as the grip of a hand.

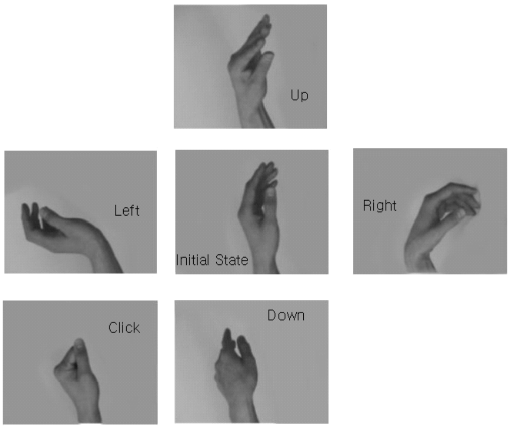


Figure 1: Wrist motions for representing up, down, left, right or click symbol.

By considering wearability of electrodes and basic knowledge in anatomy, four positions on the surface of a forearm are chosen. In the previous studies (Rosenberg, 1998; Tarng, 1997; Tsuji, 2001), EMG electrodes were attached on a forearm by using an adhesive and their locations on the forearm were scattered for getting good signal fidelity. Therefore their interface prototypes seem to be not practical because it takes time and effort to set electrodes on scattered positions.

For easy-to-wear use, we suggest that the electrodes should be located on a circle around the forearm. Then, the electrodes can be mounted to an attaching device of a band type. The chosen muscles are flexor carpi radialis, flexor carpi ulnaris, extensor carpi ulnaris and extensor digitorum communis. The attaching device is located at 1/3 times point from the elbow to the wrist.

The device prototype for attaching EMG electrodes is shown in Figure 2. The device is a band type and it is wearable. The electrodes, the DE-2.1 of Delsys Inc. are used in this study. The electrode, the DE-2.1 does not need an adhesive and it is suitable for wearability. The electrodes are attached on the mounting band by using Velcro tapes and the position of an electrode can be easily adjusted.

Figure 2: The device prototype for attaching EMG electrodes.

Figure 3 shows the situation in wearing the device prototype for attaching the electrodes. In Figure 3, the locations of the EMG electrodes are marked. The earth electrode is attached on the wrist in the figure.

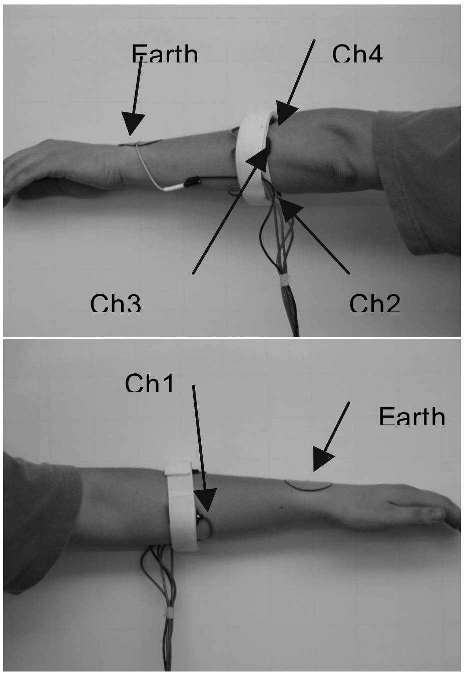


Figure 3: The situation in wearing the device prototype for attaching the electrodes. The words represent the locations of EMG electrodes. (Ch1: flexor carpi radialis, Ch2: flexor carpi ulnaris, Ch3: extensor carpi ulnaris, Ch4: extensor digitorum communis)

3 EMG signal processing methods

In this section, the EMG signal processing methods are described for distinguishing the wrist motions. In order to distinguish wrist motions, direction indication, data acquisition, feature extraction and pattern learning are needed. Figure 4 shows the schematic diagram for distinguishing the wrist motions. After the specific direction is indicated on a display, a subject, who attaches EMG electrodes on the forearm, bends his wrist according to the direction. From the EMG signals acquired by a data acquisition system, the features of the signals are extracted. Then, learning the patterns is carried out. The parameters, which are learned in the pattern learning process, are used for distinguishing new wrist motions.

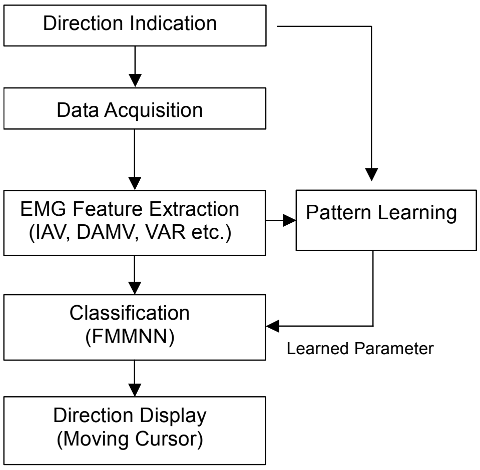
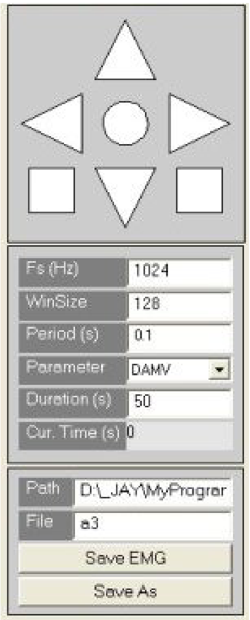


Figure 4: A schematic procedure for analysis of the EMG signals and pattern classification.

Figure 5 is an example program for displaying the indicated direction and acquiring the EMG signals. The color of the direction symbol in the figure is changed according to the given direction. After the specific direction is indicated on a display, a subject should bend the wrist toward the predefined direction. Then the EMG signals due to the specified wrist motion can be acquired.

EMG signals are acquired from a subject by repeating each wrist motion about ten times. The duration for indicating the pre-defined motion is fixed to 1 second. Since it is hard to determine the start point of wrist motion in pattern learning, the first 100 ms data acquired after indicating a direction, is not used in the pattern learning.

The indication for wrist motion can be shown up sequentially or randomly. The GUI programs are written in MATLAB®.



Fs (Hz) 1024
WinSize 128
Period (s) 0.1
Parameter DAMV
Duration (s) 50
Cur. Time (s) 0
Path D:_JAY\MyProgrсостояни
File a3

Figure 5: Example scene of executing program to acquire the EMG signals by the wrist motion according to a direction.

The Bagnoli-4 of Delsys Inc. amplifies the EMG signals by 1000 times. For data acquisition and processing, PCI-MIO-16E of National Instrument Inc. is used. The 1024 Hz and 12 bit sampling is conducted in analogue-to-digital converting.

The Features extracted from the EMG signals are used as the input vectors in learning and classifying the patterns. The feature used in this study is as follows:

- Integral Absolute Value (IAV): The IAV is calculated for each window of data according to the following equation:

$$IAV = \frac{1}{N}\sum_{i=1}^{N}|x(i)| \,, \tag{1}$$

where x is data within the window and N is window length.

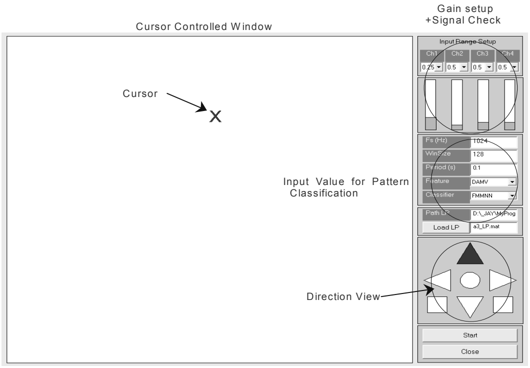
- Difference Absolute Mean Value (DAMV): The DAMV is calculated for each window of data according to the following equation:

$$DAMV = \frac{1}{N-1}\sum_{i=2}^{N}|x(i) - x(i-1)| \,. \tag{2}$$

Since the EMG with duration of 100 ms or more can be assumed statically stable (Delagi, 1994), the window length is set to 125 ms. The features at each time block are used as the input vector for pattern learning.

For learning and classifying the patterns, the Fuzzy Min-Max Neural Network (FMMNN) algorithm (Simpson, 1992) is used. The FMMNN is a kind of supervised learning neural network classifier. Each class is described as summation of several hyperbox, which is a fuzzy set, and the hyperbox is determined by *n* dimensional min-max value. The FMMNN has a nonlinear separability. The sensitivity parameter in the FMMNN controls the decay rate of a membership function and the value 4 is chosen as the sensitivity parameter in this study. The number of hyperbox at each class is 5000 and the increment degree of hyperbox is 0.005. Then, the pattern recognition rate of each wrist motions is above 90% when the DAMV is used as the feature. Since IAV or DAMV represents the power of a signal, these features give a similar recognition rate. The parameters calculated in pattern learning are saved in a file and they are used for distinguishing new wrist motions.

The Figure 6 shows a scene in demonstration program for the EMG-controlled graphic interface. The left part in the figure is area for illustrating the moving cursor and the right part is area for showing the control parameters, such as the sampling frequency and the feature name. After loading the learned parameters and activating the program, it is confirmed that the wrist motion can easily control the cursor position. Although some erroneous movement of the cursor with the wrist motion is occasionally occurred in case of changing the wrist motion suddenly, it is not difficult to move the cursor to the desired position.



Ch1 0.25
Ch2 0.5
Ch3 0.5
Ch4 0.5

Fs (Hz) 1024
WinSize 128
Period (s) 0.1
Feature DAMV
Classifier FMMNN
Path LP D:_JAY\MyProg
Load LP a3_LP.mat

Figure 6: Example scene in executing the program for demonstration of the EMG-controlled graphic interface.

4 Summary and future works

In this study, we dealt with the practical method to attach electrodes on a forearm and the EMG signal processing methods for distinguishing the wrist motion. At first, the device for attaching EMG electrodes on forearm was designed. This device makes it easy to attach the electrodes on a forearm without an adhesive. As a feature, the DAMV and the IAV are used in the EMG-controlled graphic interface. For pattern classification, the FMMNN was employed. By using the signals acquired in wearing the device, the EMG-controlled graphic interface could control a cursor's movement easily.

The future works is to realize the application for controlling mouse position more precisely than the present.

References

Park, S.H. (1999), The Biosignal Processing and Application, Edtech.

Delsys Inc. (1996), Surface Electromyography: Detection and Recording, Delsys Tutorial.

Rosenberg, R. (1998), The Biofeedback Pointer: EMG Control of a Two Dimensional Pointer, Second International Symposium on Wearable Computers, 162-163.

Tarng Y.H., Chang, G.C., Lai, J.S., & Kuo, T.S. (1997), Design of the Human/Computer Interface for Human with Disability Using Myoelectric Signal Control, Proceedings of the 19th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 5, 1909-1910.

Tsuji T, Fukuda O, Murakami M, Kaneko M. (2001), An EMG controlled pointing device using a neural network, *Transactions of the Society of Instrument and Control Engineers*, 37(5), 425-31.

Delagi, E. F., Iazzetti, J., Perotto, A., & Morrison, D. (1994), Anatomical Guide For The Electromyographer, *The Limbs and Trunk*, Springfield.

Simpson, P. K. (1992), Fuzzy Min-Max Neural Networks-Part 1: Classification, *IEEE Trans*, *On Neural Networks*, 3 (5), 776-786.