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Design of Real-Time Document Control Based on Zigbee and Surface Electromyography (sEMG)*

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ABSTRACT

The human-computer interaction (HCI) is now playing a great role in computer technology. This study introduces an automatic document control technique which is based on the human hand waving movements. The recognition of hand movement is realized according to the surface electromyography (sEMG). A collector is set on the forearm. The sEMG signal is recorded and conveyed to a PC terminal by using wireless Zigbee. An automatic algorithm is developed in order to extract the characteristics of sEMG, recognize the waving movements, and transmit to document control command. The developed human-computer interaction technique can be used as a new gallery for teaching, as well as an assistant tool for disabled person.

Keywords: Surface Electromyography; Human-Computer Interaction; Zigbee; Document Control

1. Introduction

Nowadays, PC is widely used everywhere. The normal HCI method is usually achieved with a keyboard along with a mouse or a touch screen. But it is really inconvenient for disabled people to use these equipments by themselves. The research indicated that, the difference between the electrodes stuck to the skin of muscle would change with the movement of muscle. The differences at difference time and difference movements make the surface electromyogram (sEMG). All the signals of muscle movement can be detected and recorded [1]. Recently, sEMG has been widely used in the field of rehabilitation engineering. As a member of the family of body signals, the sEMG has its unique advantages when compared with other body signals in application. First of all, sEMG is easier to collect. Besides that, sEMG has stronger strength than other signals and sEMG has more channels for experimenters to use. The normal sEMG collect method needs lots of complex electrodes linked with PC and experimenters which always make the users feel uncomfortable. The individuals can't move for long time as the EMG experiment always consumes much time, and that usually makes them very tired.

This paper proposes a new method to convey the sEMG to PC wirelessly, so there are no miscellaneous link lines across researchers and users. And all the data are collected by the instruments set on individual's forearm. The features of sEMG will be detected when the individual's hand wave up or down. The data is preprocessed first by a HPT in order to eliminate the clutters. The star topology of Zigbee was settled to build up a wireless transmit network. The sEMG signals can easily conveyed to PC rapidly. Since EMG is often contaminated by the ECG, it usually hampers data analysis and potentially yields misinterpretations. The independent component analysis method (ICA) is used to get rid of the impact of ECG. A real-time control system is invented autonomously which can receive the sEMG data, dispose the data and transmit the data to control system. The system finally comes true with stable, security and practical use.

2. Data Acquisition

The subjects of sEMG pick up experiment are ten healthy graduated students (five male, five female) whose average age is twenty-three. Eight students use their right hand as the strong hand while two use the left one. There are total four series of sEMG data obtained from experimenter's forearm. The sEMG signals were recorded at

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extensor carpi radialis muscle, flexor carpi radialis and extensor carpi ulnaris musculus according to anatomy. The actual electro position is shown in **Figure 1**.

The experiment uses an amplifier with a sampling frequency of 500 Hz, a sensitivity of 100 uV. The high-pass filter (HPF) frequency is 100 Hz while the notch filter is 50 Hz.

3. Wireless Zigbee

The Zigbee technology is famous for its advantage on low power consumption, concise, short distance and so on. Zigbee is becoming popular in our daily life. It has a particular advantage in the field of short distance and low consumption equipment transforms digital data wireless, especially during periodic and intermittent applications. It can work at the frequency of 2.4 Ghz (world wild scope), 868 Mhz (Europe scope) and 919 Mhz (America scope) allocate with the speed of 250 Kbit/s, 20 Kbit/s and 40 Kbit/s. The transport distance can range from 10 to 75 meters.

In this study, the Zigbee module works at the frequency of 2.4 GHz and the channel sets to 20 through MAC_RADIO_SET_CHANNEL(x) control command. The data will be transited in a periodicity method. Once the receiver Zigbee get into receiving status, the net-layer can receive sEMG signals through MAC service. Before the application layer receive the data, the hardware part has accomplished receiving the data and storing them in the buffer which the software can read data from buffer to achieve corresponding function [2]. The wireless transaction module performs its three functions in this system. First, it takes charge of the transformation between SEMG and PC while making sure that the information is real-timing. Second, primary dispose sEMG signal is collected from forearm. Including amplify the feeble signal and filter for the first time. At last, transform sEMG signal to PC and store them in the buffer for display online.

4. System Structure

The flow char of the system is shown in **Figure 2**. First of all, detect the sEMG plus through the electrodes fixed in forearm. Then pre-process the sEMG signal such as filtering, A/D transforming and amplifying with an amplifier. Third, transform them to PC with wireless Zigbee part, store them in the buffer memory and display them in an invented window. Fourth, deal with the digital data collected from forearm. An independent component analysis (ICA) arithmetic is put into use to digital filtering preliminary. Fifth, extract the hand wave movement, take clear of the exact movements and the number of them, output them as control signal. At last, stop and exit the system.

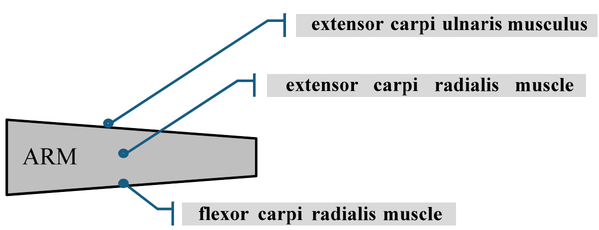

Figure 1. The actual electro position.

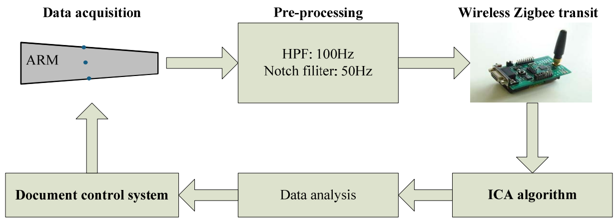

Figure 2. The flow chart of the system.

4.1. Independent Component Analysis

EMG recordings are often incorporated by the electrocardiogram (ECG), which can disturb the classifications of hand movement and result in misinterpretations [3]. Independent component analysis (ICA) is widely used for a situation involving two signal sources [4]. The diagram to the operation of ICA is illustrated in **Figure 3**.

The mixtures X are generated by the operation

$$X = AS \tag{1}$$

In this case,

$$S = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}, \quad X = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

And the mixing matrix A is given by

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$$

The aim is to estimate an unmixing matrix W that enable the signal sources U to be obtained by

$$U = WX \tag{2}$$

where

$$W = \begin{bmatrix} w_{11} & w_{12} \\ w_{21} & w_{22} \end{bmatrix}, \quad U = \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$$

The ICA algorithm is performed by each iteration, the unmixing matrix W is updated until convergence is achieved. The algorithm stops training when the rate of change falls below a predefined small value.

The description of ICA can be referred to the book by LEE [5].

4.2. Hand Wave and Number of Clench Fist

There will be a pulse when the individual wave their

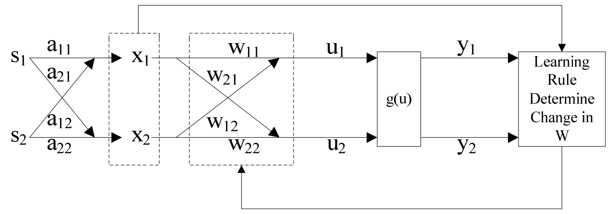

Figure 3. Diagram to illustrate the operation of ICA.

hands while the potential difference is much lower when there are no wave movements. A threshold will be defined to distinguish the hand waving movements. The data will set to zero when they are lower than the threshold while set to one when they are higher than the threshold. Then the hand wave movement and number of clench fist could be calculated exactly [6].

4.3. Control Flow Chart

The system normally operate flow the process which consist of six steps such as entering the system, selecting file list, confirming to play, documenting page up, documenting page down and exiting or replaying the system. The detailed control flow is shown in **Figure 4**,

1) Enter the system: The experimenter can clench their fist three times to enter the system when he or she enters for the first time or after stop. The other clench has no means.

2) Select file list: After enter the system, the individual could wave his or her hand from up to down or reverse to choose which file to play. Citing wave down three times means choose the third item file to play. Of course, the file list could be updated manually.

3) Confirm to play: The individual could clench fist twice to confirm the chosen file to play.

4) Document page up: When the performer needs to control the document to page up he or she could wave his or her hand from right to left.

5) Document page down: When the performer needs to control the document to page down he or she could wave his or her hand from left to right.

6) Exit or replay: The individual could replay the whole system by clench fist twice or exit the system by disconnect the wireless Zigbee part.

5. Result

5.1. Data Analysis

There are totally four series of sEMG data which indicate wave up, wave down, wave right, wave left and clench fist movement. According to anatomy, extensor carpi radialis muscle, flexor carpi radialis muscle and extensor carpi ulnaris muscle can generate electronic signals when individuals wave up or wave down and sEMG signal may change when they rotate their arm to wave right and

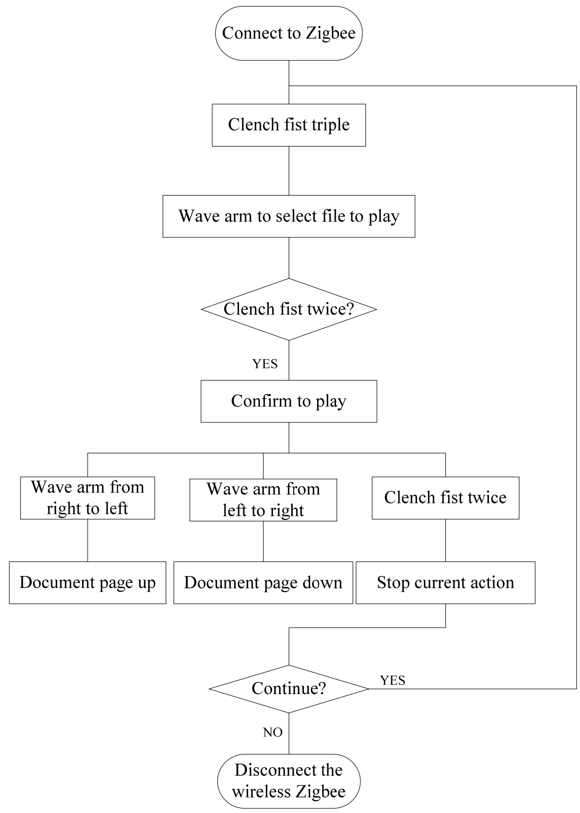

Figure 4. The detailed control flow chart.

wave left. It is also indicated that the sEMG signals are much stronger when individuals clench their fist than just wave their hand [7]. Depend on the above information, the correspond sEMG waveform is shown in **Figures 5-8** as follows.

In **Figure 5**, the sEMG data is normally under 0.3 when there is no wave movement produced. However, the sEMG data suddenly arrive to 0.5 - 1.5 when the individuals move their hand. According to the threshold we set, we can distinguish the data to zero and one for convenience of the output of control command. As in figure5, we can get that there are totally four times of wave up movement or wave right movement happened. Along with the rotate arm signals shown in **Figure 7**, there is rotate arm movement happened on the same time which indicate that the actual wave movement is wave right. The sEMG data is entirely rolling-over when individuals wave their hand down rather than wave up. The same as wave right and wave left. In **Figure 8**, we can see that the clench fist sEMG signal actually up to 2.0 - 2.5 which higher than other signals. So we can easily distinguish clench signals and wave hand signals.

5.2. Real-Time Control System

After extract the wave hand movement and the number of clench fist, the output signal can be used in the docu-

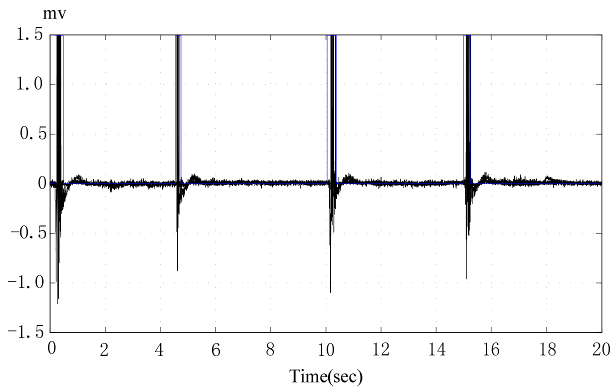

Figure 5. Wave up sEMG signals threshold analysis.

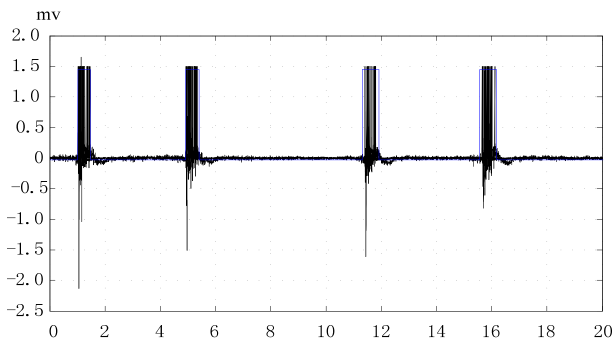

Figure 6. Wave down sEMG signals threshold analysis.

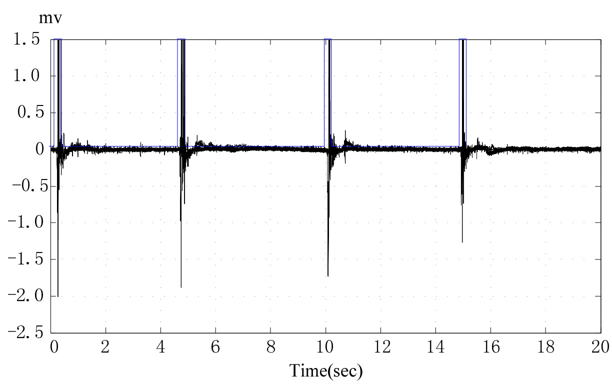

Figure 7. Rotate arm sEMG signals threshold analysis.

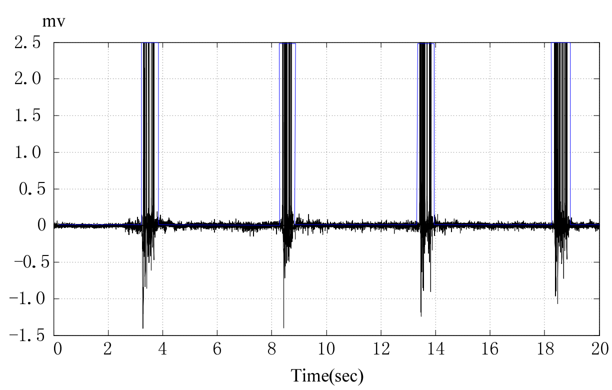

Figure 8. Clench fist sEMG signals threshold analysis.

ment control system. First, we could choose the file to play with wave hand. Second, after select the file we could control a document to display, such as page up and page down or close the document. The software is designed and executed successful on VB6.0 [8]. The MSCOM controller is used to connect with serial data from Zigbee. The HCI system is working as shown in **Figure 9** [9].

6. Result

The gap of convenience is very common between different HCI methods. In order to get more information about the proposed HCI, a survey is made in different groups. Totally twenty students whose average age is 24 are asked to make this survey. The survey information is listed as follow. Take use of an online survey system, a valuable report is shown in table1 detailed.

Question 1:

Which is the most comfortable HCI pattern?

A, mouse down; B, sEMG; C, voice

Question 2:

Which action will you take to control a PPT?

A, clench fist; B, wave hand; C, shake figure

Question 3:

Which hand waving actions will you chose to generate useful signal?

a, left to right; b, right to left; c, front to back

As the result shown in **Table 1**, about 60% people tend to take use of sEMG as control signal; 50% people familiar with wave hand to achieve document control; 60% people expect to enforce document by wave their hand

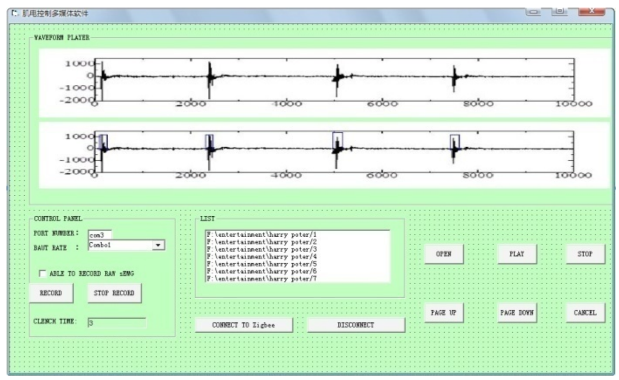

Figure 9. Document control system.

Table 1. Survey result report.

option / question	Survey result		
	No.1	No. 2	No. 3
A	5	6	2
B	12	10	12
C	3	4	6

from right to left.

According to this survey result, it is convenient for many people to select hand wave movement as document control signal.

7. Conclusions

In this paper, we propose a new HCI system which has many innovations. First of all, the control command is produced through the analysis of sEMG signals. Besides that, the wireless data transition system along with a data transit network built by Zigbee. EOG signals are eliminated from sEMG with the ICA algorithm which enhances the accuracy of control command. A computer platform is built to deal with the wireless data transit module, the recognition of sEMG, the output of control command and so on.

This paper proposes a new application of sEMG along with Zigbee technology. An online survey system is used to make sure that the most acceptable movement of document control is wave hand. In addition, the direct body movement in a speech with PPT is very natural and comfortable because body movement is the instinct of oneself. The ICA arithmetic can combine with other arithmetic such as JADE and PCA in order to get more instinct control signal. In the future, the recognition algorithm can be improved with the development of technology. This system can be used in many aspects of the society such as teaching and disabled treatment.

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