Application of facial electromyography in computer mouse access for people with disabilities

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Abstract

Purpose. This study develops a newly facial EMG human–computer interface for people with disabilities for controlling the movement of the cursor on a computer screen.

Method. We access the computer cursor according to different facial muscle activity patterns. In order to exactly detect the muscle activity threshold, this study adopts continuous wavelet transformation to estimate the single motor unit action potentials dynamically.

Result. The experiment indicates that the accuracy of using the facial mouse is greater than 80%, and this result indicates the feasibility of the proposed system. Moreover, the subject can improve performance of manipulation by repeated training.

Conclusion. Compared with previous works, the proposed system achieves complete cursor function and provides an inexpensive solution. Although there are still some drawbacks in the facial EMG-based human–computer interface, the facial mouse can provide an alternative among other expensive and complicated assistive technologies.

Keywords: Facial electromyography, assistive technology, disabilities

1. Introduction

Nowadays, the ability to operate a computer has become more and more important for modern people. Computer technology has brought many utilities and great convenience in daily life [1]. The significant development of the Internet is one of the most famous and essential applications of computers. The Internet provides users many services, such as shopping, news, downloading multimedia, etc., without going out of the home. Especially for quadriplegics, because of their disablement, their interaction with the outside world becomes more and more difficult. With the assistance of computers, they can acquire information about the outside world and access the environmental control unit; the computer can not only improve living quality, but can also create employment opportunities [2].

With the growing GUI (graphic user interface) software environment, the computer mouse has become the major input device. Through the computer mouse, users can skillfully move the cursor and accurately activate buttons on the screen. Nevertheless, the hand mouse is unreachable for individuals who have severe disabilities, such as quadriplegia and amyotrophic lateral sclerosis. Therefore, the development of another human–computer input device is necessary and pressing.

A number of approaches have attempted to make the human–computer interface accessible for people with disability. Presently, input assistive technology for the personal computer includes the mouthstick, a head-controlled system [3,4], an eye-controlled system [5,6], and an EEG brain–computer interface (BCI) [7]. However, those devices still have some drawbacks in practical application. For instance, people with cerebral palsy may not have the fine motor abilities necessary to operate the mouthstick, and the user may find it hard to watch the pointer moving on the screen while targeting the keyboard with the stick. The eye-controlled methods are based on electrooculography signals or eye movement...
images for developing an input device. Even though the eye-controlled input does not presume any mechanical capability on the part of users than other controls, it requires great attention and effort to achieve proper control. The performance of the head-controlled system is easily influenced by the movement of the subject and changes in the environment. Employing the image-processing method can compensate the motion effect, but unfortunately eye gaze tracking raises the complexity and the cost in implementation. The BCIs utilize information extracted from slow cortical potentials, P300 evoked potentials, μ and β rhythms, and cortical neuronal potential. For picking out a weak BCI signal in a noisy environment, signal-processing algorithms need to be improved. Even with the latest modern techniques, such systems still suffer from slow communication rates.

EMG signals are considered mostly to be the noise source in the above human–computer interface application. For example, in the EOG-based eye mouse and EEG-based BCI system, EMG signals often disturb interesting signals. EMG artifacts can appear in any site and have a high signal-to-noise ratio, so it is not easy to eliminate these artifacts completely. In contrast to reducing EMG artifacts, we can try to utilize muscle activity signals to control computers for people with disabilities. For example, Barreto et al. [8] designed an EMG/EEG human–computer interface that employs biosignals gathered from the head of the subject to be used as the control pattern of cursor movement. Chen et al. [9] also used the surface electromyography (SEMG) sensing input to provide an input option for the disabled. This SEMG mouse input can avoid scanning of unnecessary keyboard characters, thereby increasing the speed in performing mouse commands. The EMG HCI pattern is a potential application in human–computer interface applications for people with disability. The EMG can provide a rich pattern combination from every different motor unit. This feature seems applicable for achieving computer functions, such as cursor movement, right button click, left button click and dragging. Moreover, we can control the cursor speed by varying EMG amplitude. Thus, the user is capable of nimble movement of the cursor across long distances and of detailed typing using the operating system-built ‘on-screen keyboard’ without alternative assistive software.

2. Method

The goal of this paper is to develop a human–computer interface for quadriplegics who cannot use their hands or arms, but at least can control their facial muscles. For paralyzed subjects, whose paralysis is the result of accident or illness, the facial muscles may be the last available motor unit. As we know, the facial muscles are a small three-dimension combination of muscular slips carrying out a variety of complex orofacial functions. All facial functions, such as speech, mastication and facial expression, are accomplished by individual muscles. Any muscle movement on the face can provide EMG control patterns. So we can combine different facial muscles to generate a rich control pattern. Therefore, we chose the facial EMG as a control signal. The proposed EMG human–computer interface employs the EMG signal gathered from the human face to control the computer cursor. A block diagram of the facial EMG pattern control system is shown in Figure 1. Firstly the active electrodes pick up the EMG coming from the natural and voluntary movement of the user’s face. After pre-amplifying, the data acquisition card converts the EMG signal to digital values and stores the data in the PC. In order to accurately detect the facial muscle activity in real time, we use CWT (continuous wavelet transform) to estimate the EMG activity threshold. The entire signal-processing algorithm is developed using the graphical development environment, Labview. Eventually, the pattern-recognition scheme launches the corresponding computer mouse function according to the muscle activity pattern. Using the facial EMG cursor, the disabled subject can access the computer software by their contracting facial muscles.

![Figure 1. Block diagram representation of the facial EMG pattern control system.](image-url)
2.1 Facial EMG signal acquisition

Because the amplitude of facial EMG is very weak, the signal is easily impaired by many external interferences. The differential electrode configuration can reduce the cross-talk and the noise in the EMG signal detected by the surface electrodes. But the facial muscles are too thin for the location of bipolar surface electrodes. Furthermore, if we attach too many electrodes on the face, they could hamper the movement of facial muscles. So the differential electrode configuration is not a suitable solution to facial EMG recording. For this reason, an active EMG electrode (BioEngineering Sense Tech Inc.) of CMRR 128 dB and high input impedances 10 GΩ are applied in this work. The high input impedance of active electrodes will lower the influence of the skin–electrode interference and reject common mode noise, especially power line interference. For preventing the cross-talk problem, a voltage follower circuit with unity gain is applied for each high-impedance signal source before connecting to the DAQ device. Finally, facial EMG signals, which are picked up by the active electrodes, are digitalized at 2000 samples/s using a data acquisition card (NI 6014; National Instruments).

2.2 Facial EMG activity detection scheme

The estimation of on-off timing on human skeletal muscles during movement is an important issue in surface electromyography (EMG) signal processing. In this paper we adopt a fast and reliable continuous wavelet transform (CWT) to detect the muscle activity from surface EMG signals [10]. This CWT method can identify the presence of single motor unit action potentials (MUAPs) from the surface EMG signal. To extract MUAP from EMG, we have defined a mother wavelet function that is similar to the MUAP shape in order to decompose the EMG signal. Since the surface EMG signal is the summation of MUAP trains, we can separate the EMG into MUAP and non-MUAP (noise) parts (see Appendix for a more detail derivation).

This detection scheme can estimate the noise level according to measurement conditions without finely tuning a proper threshold. This would be an important feature in applying facial EMG signals to the recognition of computer mouse patterns. Figure 2 can help to define the facial EMG activity detection scheme and cursor function classification. Figure 2(a) shows single-channel facial EMG activity detection by CWT. In order to accomplish a
complete cursor function, four single-channel EMG detections are connected to create enough control pattern combination, as shown in Figure 2(b). The next section explains the decision-making scheme in the classification of cursor function.

### 2.3 Computer mouse control pattern

Since facial EMG activity can be detected successfully, we need to explore opposite muscles to generate facial EMG control patterns. Owing to the fact that the fibers of the facial muscles are very thin and close to the facial tendon, electrode placement will influence the amplitude and spectrum of the facial EMG signal [11]. Through practical examinations, we chose to put the electrodes on four facial muscles including both sides of orbicular, masseteric and mentalis muscles. Figure 3 illustrates the expected electrode position and facial muscle anatomy. After setting the surface electrodes on the face, we can perform a series of muscle-specific facial poses and then EMG signals are recorded simultaneously from different muscles. Each pose can be selected to activate a particular muscle, thus can we control the computer mouse by expressing different facial poses. Table I shows the comparison between mouse function and the corresponding facial movement.

While manipulating the computer mouse, moving the cursor is the most often used action. It is a high priority to define each facial muscle activity for every direction: up, down, left and right. Furthermore, different combinations of four basic control patterns can perform more computer mouse functions, such as clicking and dragging. Moving the mouse in the opposite direction simultaneously is an incompatible situation, so we apply the opposite direction pattern to the mouse button function. For this reason, the contracting of masseteric and mentalis muscles is defined as left button clicking. In the same way, right button clicking has been presented while activating on both sides of orbicular muscles. From Table I, we can observe that moving down and left button double click depend on the same pattern, the mentalis muscle. This is because mentalis EMG is easy to pick up and handle, thus the down and double click function can be determined by different levels of muscle contraction. When the user slightly pouts his lip, the cursor moves down on the screen. If the EMG amplitude of pouting the lip is greater than the double click threshold, the cursor performs the double click function. Figure 4 illustrates four active electrodes, which are attached to the selected muscles.

### 3. Result

In order to assess the feasibility of practically applying the facial EMG computer interface, a test program was developed in Labview to examine the

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**Table I. The comparison between electrode position and mouse function.**

<table>
<thead>
<tr>
<th>Mouse function</th>
<th>Electrode position</th>
<th>Facial movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Left orbicular muscle</td>
<td>Winking left eye</td>
</tr>
<tr>
<td>Right</td>
<td>Right orbicular muscle</td>
<td>Winking right eye</td>
</tr>
<tr>
<td>Up</td>
<td>Masseteric muscle</td>
<td>Gritting the teeth</td>
</tr>
<tr>
<td>Down</td>
<td>Mentalis muscle</td>
<td>Slightly pouting the lip</td>
</tr>
<tr>
<td>Single click (left)</td>
<td>Masseteric &amp; mentalis</td>
<td>Gritting the teeth &amp; pouting the lip</td>
</tr>
<tr>
<td>Double click (left)</td>
<td>Mentalis muscle</td>
<td>Strongly pouting the lip</td>
</tr>
<tr>
<td>Single click (right)</td>
<td>Left &amp; right orbicular</td>
<td>Wink the right and left eye</td>
</tr>
</tbody>
</table>

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**Figure 3. Illustration of the placement of electrodes and facial muscle anatomy.**
pointing and the clicking capabilities of a facial EMG mouse. The test program records the time cost and the accuracy of the subject for fulfilling the given cursor commands. The facial muscle human–computer interface is shown in Figure 5, which indicates the raw facial EMG and the cursor status. This information can help to setup the SNR factor and provide a visual feedback of the controlled cursor movement.

In this paper, the facial EMG computer interface was tested on six subjects who have experience in operating computers. All of the subjects are healthy male volunteers aged 24–27. Every subject had 30 min training prior to using this newly developed computer mouse. The subjects were assigned 12 instructions to perform complete cursor functions (up, down, left, right, upper-left, upper-right, lower-left, lower-right, drag, single click, and double
clicks). According to a given command, the user executes the corresponding facial movement to control the cursor on the screen. After finishing 12 cursor functions, the percentage of accuracy and the time cost for every trial were calculated. Each subject repeated commands five times per trial. Table II shows the accuracy for each subject in performing the assigned instructions, and Table III illustrates the time cost for each subject to complete the full cursor function. Figure 6 indicates the accuracy and the average time cost for each subject.

4. Conclusion

In this paper we have developed a real-time facial EMG human–computer interface for controlling a computer cursor. From Figure 6, we can see that each subject performs with different accuracy and time cost in cursor function trials. The reason for this result is that everyone has a different manner of using the facial muscles. Moreover, Table III shows that the time cost is decreased gradually for each trial. This indicates that the control performance of a facial cursor can be improved by repeated training. Through adequate training, all users can achieve an accuracy of at least 80% and this result proves the great feasibility of the proposed system.

Some previous computer mouse designs for use in disability have been restricted to limited functions, such as only moving or single selecting. So the user has to choose the desired character or command through single key input by using row-column scanning. The newly developed system can achieve complete mouse function (up, down, left, right, upper-left, upper-right, lower-left, lower-right, drag, single click, and double clicks) using the combination of a four-channel facial EMG signal. This could promote the practical value of the proposed system. Furthermore, we have carried out many applications in practice, such as word typing, Internet access and email use.

Since this system has accomplished a full computer mouse function, the user can achieve intuitive manipulation of the computer cursor through the remaining controllable muscles without the necessity of an alternative assistive program. So the subject can achieve acceptable results in carrying out cursor movement without requiring long-term operational training. The facial EMG computer mouse can be a viable alternative to other expensive methods.

Still, there are some drawbacks in using the facial EMG. The facial mouse may not be acceptable for people who do not have good control of the facial muscles. Another disadvantage of EMG-based systems is that electrodes may fall off when the electrodes have been worn for a long time or if the

| Table II. The accuracy (%) for each subject in completing 12 commands. |
|-----------------|------|------|------|------|------|------|
| Subject | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Average |
| 1     | 83.3  | 83.3  | 83.3  | 83.3  | 91.6  | 84.96  |
| 2     | 83.3  | 83.3  | 66    | 91.6  | 91.6  | 83.16  |
| 3     | 83.3  | 83.3  | 75    | 91.6  | 100   | 84.64  |
| 4     | 83.3  | 91.6  | 83.3  | 83.3  | 100   | 88.3  |
| 5     | 83.3  | 83.3  | 83.3  | 83.3  | 83.3  | 83.3  |
| 6     | 83.3  | 83.3  | 83.3  | 91.6  | 91.6  | 86.62  |

| Table III. The time cost (seconds) for each subject to complete the 12 assigned commands. |
|-----------------|------|------|------|------|------|------|
| Subject | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Average |
| 1     | 79     | 66     | 58    | 47    | 46    | 59.2   |
| 2     | 58     | 56     | 53    | 51    | 40    | 51.6   |
| 3     | 63     | 51     | 36    | 33    | 32    | 43     |
| 4     | 44     | 37     | 35    | 32    | 31    | 35.8   |
| 5     | 38     | 35     | 32    | 25    | 22    | 30.4   |
| 6     | 46     | 36     | 35    | 31    | 27    | 35     |

Figure 6. The accuracy and the average time cost for each subject.
user is sweating. In the future, we hope to develop a new skin attachment technique that yields firm electrode fixation. In addition to the facial mouse application, this interface could be applied in many control systems, such as powered wheelchairs, physiological robots and environmental control systems. All the aims of our work are to help quadriplegics open up their view of the world and to live with more dignity.

References


Appendix

Wavelet transform for facial EMG detection

The wavelet transform described in this article to detect the activity of facial muscles from EMG signals: the continuous wavelet transform (CWT) is defined as

$$\text{CWT}(a, \tau) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} s(t) \cdot \varphi^{*}(\frac{t-\tau}{a}) \, dt$$  

(1)

where \(s(t)\) is the signal to be analyzed, \(\varphi(t)\) is a prototype function called mother wavelet, \(\tau\) is a translation index, and \(a\) is a scale parameter related to the frequency content. In this paper we chose a mother wavelet function that is similar to the MUAP shape to decompose the EMG signal. The first-order Hermite–Rodriguez function \(HR_1(t)\) is adopted as mother wavelet \(\varphi(t)\) to describe the basic MUAP shape [12].

$$HR_1(t) = K_{n,1} \cdot H_1 \left( \frac{t}{\lambda_n} \right) \cdot \exp(-t^2/\lambda_n^2)$$

(2)

Then we define the function \(\eta(t)\) to detect the presence of MUAPs.

$$\eta(t) = \text{Max} \{ \text{CWT}(a, t) \}$$

(3)

Before detecting the EMG activity, we need to estimate the noise level as EMG activity threshold. The threshold on the function \(\eta(t)\) is selected considering an initial period \((0 < t < T_{\text{noise}})\) in which EMG activity is not present. The variable \(M\) of the maximum value of the test function \(\eta(t)\) within initial interval is used to set the threshold value \(th\) as

$$M = \text{max} \{ \eta(t) \}, \quad \text{for} \quad 0 < t < T_{\text{noise}}$$

(4)

$$th = \gamma \cdot M$$

(5)

where \(\gamma > 1\) and \(\eta(t)\) is defined in (3).

The symbol \(\gamma\) is a factor referred to as the EMG signal noise ratio. If the SNR is high, the choice of the value is not critical, since the amplitude difference between EMG signal and noise is large. The threshold \(th\) is used as the manifestation variable to detect EMG activity.