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An Eyes Text Input Device for Persons with the Motor Neuron Diseases

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Abstract. This study proposes an eyes text input device by electro-oculogram (EOG) recognition for individuals with the motor neuron diseases. In this study, the level of the unstable EOG signal is transformed into standard logic level signal by using the baseline tracing algorithm. The standard logic level signal is used as Morse code sequences which is recognized by the sliding fuzzy recognition algorithm embedded in a microprocessor. The result demonstrates that the unstable EOG signals can be successfully transformed into alphanumeric characters and the recognition rate is approximately 99% for the novice users. Accordingly, individuals with the motor neuron diseases can input text with their eyes to access the computer and household appliances, such as lamps, fans, and TV sets.

Keywords: EOG, Disability, Assistive technology

1. Introduction

The motor neuron diseases (MNDs) are a group of progressive neurological disorders that destroy cells which control essential muscle activities such as speaking, walking, breathing, and swallowing. Normally, messages from nerve cells in the brain (called upper motor neurons) are transmitted to other nerve cells in the brain stem and spinal cord (called lower motor neurons) through to particular muscle. While disruptions in these signals can result in gradual muscle weakening, wasting away, and uncontrollable twitching (known as fasciculations). Eventually, the ability to control voluntary movement can be lost, such as smyotrophic lateral sclerosis (ALS), which has caused in sufferers' inability to make any functional movements other than those involving their eyes.

With advanced information technology, there are many assistive tools developed for disabled people with different needs to interact with the environment. Morse code and eye tracking are the most widely used technologies among other assistive devices for the severe disabled. Especially for those with Motor Neuron Diseases (MNDs) and the spinal cord injuries, Morse code is a very efficient tool [1],[2]. Morse code is typically used to represent alphanumeric characters by a series of tone and silent elements. A tone element (switch down) can be a dot (a short beep) or a dash (a longer beep); while a silent element can be a short pause between dots and dashes of a character (or a dot-space) or a longer pause between characters (or a character-space). Both of the standard Morse code tone ratio (dash/dot) and silent ratio (character-space/dot-space) are required to be 3:1.

Nowadays, there are many forms of switches to input Morse code such as a single switch of blow type, bite type, eye gaze type, etc. [3],[4]. Users can select one fit and comfortable Morse code switch, however it often takes longer time for a user to learn and practice before he/she can achieve an acceptable level of typing speed and pattern in order for Morse code (with stable tone and silent ratios) to be recognized.

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However, Morse code entered by individuals with physical limitations is generally very unstable, it is difficult to maintain stable dot (or dot-space) interval and stable tone (or silent) ratio [5]. In order to simplify the Morse code entry, several algorithms were utilized to recognize the various Morse code typing pattern for different users. After 1995, several algorithms [5]-[12] were used to recognize unstable Morse code by utilizing adaptive or neural network signal processing techniques. Although it has successfully solved the problem of irregular typing speed, it adds more complexity to the mathematic computation, except for fuzzy algorithm [11] which is embedded in a single-chip microprocessor as a portable real time recognition device.

In addition to Morse code, the eye tracking method is another useful alternative for individuals with physical limitations over their hand movements. The eye tracking device traces the movement of eyes and allows users to navigate through the web. Special software allows the user to type, and may include word-completion technology to speed up the process. However, these systems are very expensive, costing thousands of US dollars, so they are less common than those less sophisticated devices, such as mouth sticks and head wands [13]. A system working with electro-oculography (EOG) signals for a computer mouse substitution is Eagle Eyes, developed at Boston College by DiMattia and Gips [14]. Mouse-clicks can be performed via a selectable dwell time. Eagle eyes provide several software applications for education and entertainment, and thus gives support to young people with severe disabilities. An EOG based system shown by Wiebe [15], tries to ease the mounting problems of electrodes by incorporating them into eye-glasses. Additionally, an accelerometer was mounted on the glasses, hence the system can combine EOG- and acceleration signals to calculate head movements and gaze direction. In analyzing the drift of EOG signal, they measured it on the signal generated by circular patterns and horizontal long-term signals. Within an interval of 60 seconds the level of drift can raise up to a range of 0.2 volt, almost half of the EOG reference signal [16]. A common problem to all biosignal-based interfaces is that the signal is susceptible to interference and accuracy is not enough. So the application of the biosignals control system is not widespread from 1996 to 2009 [14]-[18].

Since the lateral of ALS are not suitable for wearing a complex assistive tool, the purpose of this study is to provide a text input device by eyes' movement, named "Eyes Morse code Text input device (EMcTin)". EMcTin is composed of an EOG input interface and a Morse code recognition device. Applying the baseline tracing algorithm to overcome the signal drift problem, the EOG input interface measures the EOG signal of the user and converts those into Morse code signal. For the Morse code recognition device, we develop a Morse code automatic recognition algorithm to recognize Morse code and convert it into alphanumeric characters. The recognition algorithm is very simple so that fast calculation can be easily realized on a single-chip microprocessor for real time recognition. Using EMcTin, users with Motor Neuron Diseases can input Morse code text and control the mouse pointer to access their computers with eye movements, hence to effectively communicate with the general public. In addition, it is possible for users to control some household appliances such as lamps, fans, and TV, if the smart home devices are properly facilitated.

2. Method

The structure of EMcTin composed of an EOG input interface and a Morse code recognition device [19] (as shown in Figure 1).

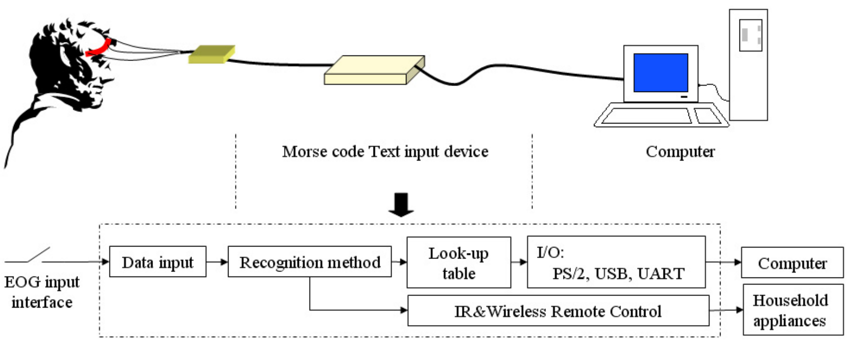

Fig. 1. The structure of EMcTin

2.1. EOG Input Interface with Baseline Tracing Algorithm

The EOG input interface is designed for the lateral of ALS to input Morse code with their eyes moving left or right allowing them to communicate with others. Due to the unstableness (or momentary variation) of EOG signal, it is difficult to detect the eye movement correctly. By using the baseline tracing algorithm, the EOG input interface can translate the EOG signal into standard logic level to generate the Morse code sequence.

Two types of EOG input interface are designed to satisfy different requirements of users. Firstly, single-switch Morse code allows users to move his/her eyes to one direction in order to generate a tone element [20]. According to the round trip time of the eye movements to and from one direction, the tone element can be identified as a dot or a dash. Secondly, two-switch Morse code with which the user can move his/her eyes to two opposite directions (such as upper-left and upper-right, up and down, or left and right) to generate a dot or a dash. This paper will describe the construct and properties of EOG two-switch type.

2.2. EOG Input Interface as Two-Switch Morse Code

The structure of the EOG two-switch Morse code input interface is shown in Figure 2. The EOG signal detection method is the same as the single-switch Morse code of the EOG input interface.

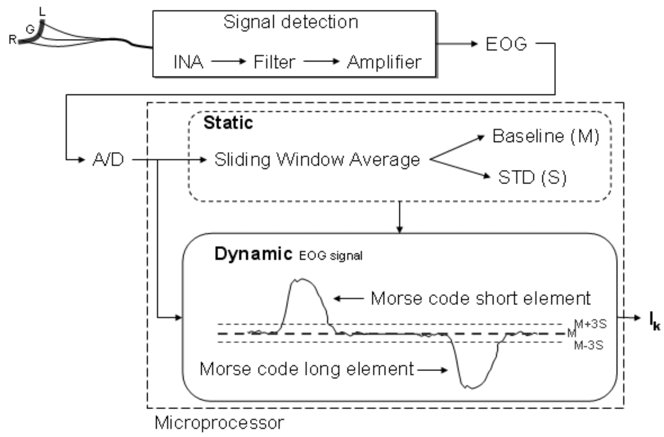

Fig. 2. The structure of EOG two switch

Using the EOG input interface as two-switch Morse code, the user can generate the tone elements of Morse code by controlling the two opposite directions of his/her eye movements. The sliding window average (SWA)[19] is used to calculate the mean value M and the standard deviation S of the latest EOG signal. When user's eyes are in the dynamic state (i.e. eyes' moving) and the EOG signal is larger than the critical level of $M+3S$, the generated signal I_k is encoded as a dot; while the EOG signal is less than the critical level of $M-3S$, the generated signal I_k is encoded as a dash. By translating the signal I_k, the Morse code recognition device is responsible for generating the corresponding alphanumeric characters.

2.3. Morse Code Recognition Device with the Sliding Fuzzy Recognition Algorithm

The signal I_k from the EOG Morse code input interface is usually an unstable Morse code sequence due to difficulty to maintain fixed tone ratio and silent ratio with eyes movement for disabled people. Therefore, an automatic Morse code recognition algorithm (called the sliding fuzzy recognition algorithm) is developed to recognize the unstable EOG Morse code sequence. The sliding fuzzy recognition algorithm combines the SWA and the fuzzy recognition algorithm. As shown in Figure 3, the *LSR* refers to the Long-to-Short Ratio of Morse code input signal I_k; the x_k refers to normalized Morse code input signal; the e_k refers to the difference between the input signal x_k and the output signal y_{k-1}; the e'_k refers to the modified value of e_k from the fuzzy algorithm; the y_k refers to the predicted output; and the T_k refers to the threshold value to distinguish between dots and dashes. The initial value of T_k is set to be 3. The system can automatically adjust the threshold value T_k to trace the baseline of varying typing speed and the varying ratio of long to short elements. The look-up table in Fig. 3 is used to translate the identified Morse code elements to the corresponding alphanumeric characters.

3. Results

To evaluate the performance of the EOG input interface, we conducted the robust test and the experimental test of EMcTin.

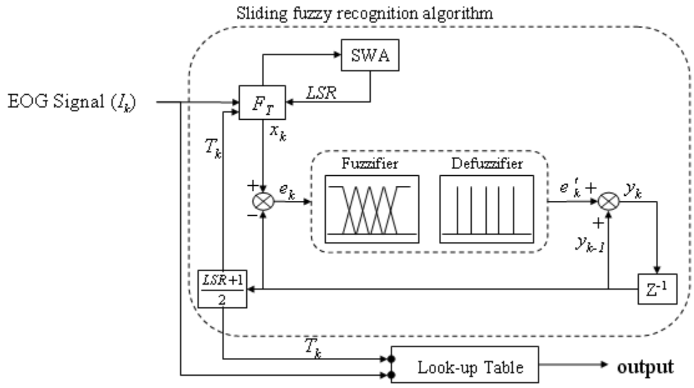

Fig. 3. The sliding fuzzy recognition algorithm [19]

3.1. Robust Test of the EOG Input Interface

During the process of measuring physiological signals, certain actions (such as adjusting the position) normally lead to drifting in signals and cause instability. Therefore, this study developed a baseline tracing algorithm that will adjust the recognition threshold (i.e. critical level) according to changes in signals to enhance the robustness of system. Fig. 4 shows the Morse code output signals of characters 'a' to 'j' by EOG switch and shows the robust test of EOG input interface with the baseline tracing algorithm. Fig. 4 (a) shows the recognized threshold of EOG sequences without the baseline tracing algorithm, Fig. 4 (b) represents the recognition result without the baseline tracing algorithm that can only successfully recognize characters 'a' to 'e'; Fig. 4 (c) illustrates the recognized threshold of EOG sequences with the baseline tracing algorithm and Fig. 4 (d) demonstrates the recognition result with the baseline tracing algorithm that can recognize all characters from 'a' to 'j' successfully. As shown in Fig. 4 (a) and Fig. 4 (c), the bold line is the baseline of the digital signal of the original EOG signal converted by ADC and the dot line is the triple-variation of EOG baseline signal. When the user inputs Morse code by the eyes, the level of EOG signal frequently drifts from time to time. Hence the baseline tracing algorithm is used to trace the baseline variation of EOG signal in the static state. Through the baseline tracing algorithm, the EOG single switch can convert the Morse code signal sequence into standard logic level as show in Fig. 4 (b) and Fig. 4 (d), the recognition rates are 45.16% and 100% respectively.

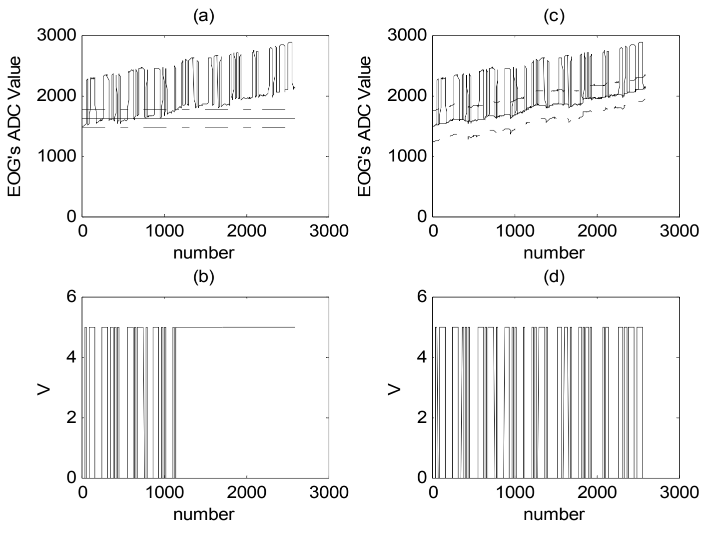

Fig. 4 The robust test of EOG input interface: (a) EOG sequences without baseline tracing algorithm (b) the recognition result without baseline tracing algorithm (c) EOG sequences with baseline tracing algorithm (d) the recognition result with baseline tracing algorithm

3.2. Experimental Results

To reduce cost and size, this study implemented EMcTin with a microprocessor as shown in Fig. 5. Fig. 5 (a) shows the EOG input interface and Fig. 5 (b) the Morse code translate input device. The experimental test of Morse code typing with EMcTin was conducted after our implementation as shown in the left part of Fig. 5.

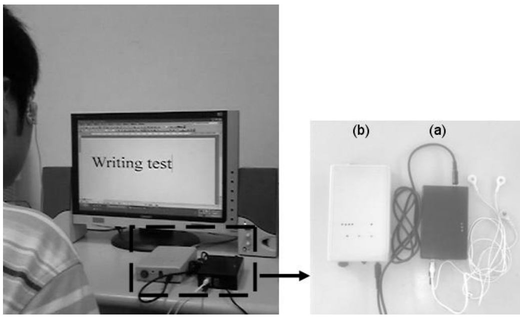

Fig. 5 The photograph of EMcTin and typing test by user: (a) EOG input interface (b) Morse code translate input device

Three new users were asked to perform ten typing tests of Morse code with a sample of alphabets form ‘a’ to ‘z’ when they have practiced the Morse code input for two hours. Users entered the Morse code sequence with the corresponding characters appearing on the display. Each user’s typing pattern and speed were recorded, and results are reproduced in Table 2 below. The average recognition rate was approximately 99.15% and the typing took about 93.44 seconds for all data.

Table 2 The results of the typing test by three novice subjects

Subject 1		Subject 2		Subject 3	
recognition rate	time	recognition rate	time	recognition rate	time
98.17	96.59	98.78	106.47	97.56	110.58
99.39	96.56	98.17	97.94	100	94.6
100	94.76	98.17	94.83	98.78	101.77
100	80.84	99.39	92.26	100	99.82
100	94.18	99.39	99.76	98.78	100.24
98.78	100.79	99.39	92.35	100	91.92
100	86.63	99.39	92.4	99.39	84.98
100	95.41	98.78	105.65	97.56	76.96
99.39	87.49	100	100.22	98.78	68
98.78	94.45	100	91.24	97.56	73.46
99.45	92.77	99.15	97.31	98.84	90.23

4. Conclusions

Patients with physical disorders experience different level of injury, they require different auxiliary input interface. Physiological signal is the better communication device than the normal control signal for patients with severe physical disabilities. However, during the process of measuring physiological signals, the subject was required to keep static to maintain a stable signal, so the application of the physiological signals is not widespread in the control system. The unstable EOG signal is converted into standard logic level signal by using the baseline tracing algorithm. The standard logic level signal is used as Morse code sequences which is recognized by the sliding fuzzy recognition algorithm embedded in a microprocessor. The results demonstrate that the unstable EOG Morse code sequences can be successfully recognized by the fuzzy recognition algorithm to generate alphanumeric characters.

In the experiment, the user can input the character stably and correctly by EOG input interface, but eyes can get tired easily if used for a long time hence resulting in unstable Morse code sequences. When using the EOG two-switch Morse code, the user inputs Morse code by controlling the two opposite directions of his/her eye movements, that can input Morse code easily and don’t care the ratio of long and short element, but increase eyestrain and uncomfortable from eye movements. Improvements on these defects will remain an important issue in the future. Additionally, functions of the EMcTin can be enhanced in the future by incorporating users' comments. Hopefully, EMcTin will be a powerful assistive communication tool for users with Motor neuron disease to communicate to the general public.

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