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Design of The Human/Computer Interface for Human with Disability — using Myoelectric Signal Controlled

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Abstract-The purpose of this study is to develop a human-computer interface(HCI) application based on a real-time EMG discrimination system. A personal computer with a plug-in data acquisition and processing board containing a floating-point digital signal processor are used to attain real-time EMG classification. The integrated EMG is employed to detect the onset of muscle contraction. The cepstral coefficients derived from AR coefficients and estimated by a recursive least square algorithm, are used as the recognition feature. These features are then discriminated using a modified maximum likelihood distance classifier. The identified commands control the mouse cursor. It is fully compatible with Microsoft serial mouse. This system can move the cursor in four directions, and double-click the icon in GUI operating systems.

Introduction

Electromyography (EMG) detected by surface electrodes is roughly the summation of all motor unit action potentials generated in the proximity of the electrodes. Owing to its noninvasive characteristics, this signal is welcome and has been applied in diverse fields including pathology identification, muscle function assessment, fatigue analysis, biomechanics and pattern classification for the last years.[1]-[4] Advanced processing methods provide the investigators with more and more precise and user-friendly tools for signal characterization, analysis and classification.

The use of above-lesion EMG as a command signal is more intuitive and much more attractive than other unnatural control methods. The use of EMG as a logic command is achieved by discriminating EMG patterns of the specified limb motions. The identification of EMG signature is fundamentally a pattern recognition problem. An entire task in pattern recognition can be divided into three phases : data acquisition, feature extraction and classification.[5]

As with the joystick or trackball, developing such a EMG discrimination system will have benefits for C5/C6 quadriplegic patients who are unable to operate the mouse.

Methods

Pattern Recognition

The schematic diagram of this pattern recognition algorithm is shown in *fig1*

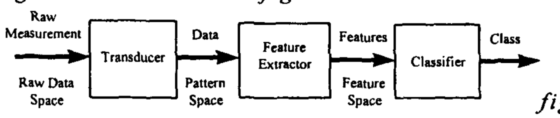

fig1

In the first stage, analog data from the physical world are gathered from a transducer(the surface electrode, amplifier and filter for EMG) and converted to digital format suitable for digital signal processing. The correlation of the signal at a single site with more than one limb function is due to the spatial integration effect of muscle fiber and skin tissue that affects the signal as measured by surface electrodes.[6]

The function of feature extraction is to preprocess the raw patterns. Recursive least square algorithm[7] is statistically efficient and exhibits near optimum convergence rates, it is suitable for real-time signal processing and is used to estimate autoregressive(AR) coefficients. The AR model for the signal is given by *eq1*.[8]

$$y(k) = -\sum_{i=1}^{P} a_i \, y(k-i) + e(k) \qquad k = 0,1,2,\ldots \qquad \text{-- } eq1$$

The first P cepstral coefficients can be obtained from the P-th order AR coefficients.[9][10] Feature vectors of the same class are expected to be concentrated in a region far away from those regions of other classes, but overlap between regions occurs occasionally.

Once the feature is settled, the performance of the pattern recognition system is determined by the classifier that sets the decision boundaries and divides the space into regions of categories. The parameters used in the maximum likelihood measurement(MLM) classifier[11][12] are either calculated based on a priori information of statistics of patterns to be identified, or are adjusted during a training process.

Designing the HCI system

Real-time processing offers the important advantage of allowing the recognition results to be immediately available. In this study, a DSP system(*fig2*) with real-time EMG pattern recognition using cepstral features and a MLM classifier as a control command of the HCI is established. There are three major parts: two channel differential amplifiers with anti-aliasing filters, a data acquisition and processing board (DS1102 manufactured by dSPACE GmbH), and a personal computer. A DSP program is loaded to the program RAM.

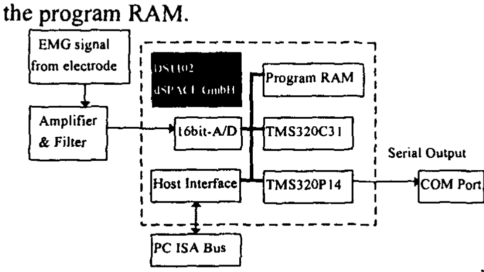

fig2

The GUI operating systems such as Windows or OS/2 are very popular in recent years. A revolutionary input device -- mouse is ideal for these operating systems. If the HCI system is compatible with mouse, strong software supports and peripherals is available worldwide. Designing this system to be fully compatible with mouse gives great flexibility and applicability than controlling a single graphical object.

This system identifies five motions and controls four direction movements and double-click. Users do not need to keep this motion correctly after the mouse cursor starts moving. Just keep making muscle contraction. Mouse cursor will keep moving if IEMG is still larger than a threshold value. The IEMG is defined as the absolute summation of EMG in a fixed data length. It stops moving when the muscle is relaxed. Designing this control mechanism replaces mouse functions but drag-and-drop.

The classifier needs a reference feature space before use. Means and variances in one motion is derived from more than five repeating motion. Setting up a good reference feature space gives excellent recognition ratio. The user will establish the reference feature space again if he need a better one. An on-line windows program written in C++ helps setting up reference feature space and adjusting the IEMG threshold is developed.

Many complex factors from human body confuse this system. Many constant variables in the program are adjusted to have a optimum performance by experience. Electrode placement have to give the maximum feature separation and higher signal level. Designing the four direction movements speeding up after a short time saves the time moving to a far position and gives good resolution in short movement.

Results

Five gold surface disc electrodes with conductive paste were bilaterally placed on and between the upper trapezius and the sternocleidomastoid. For each pair of two electrodes, one was located over the sternocleidomastoid and the other over the upper trapezius. A ground electrode was attached to the right earlobe. The skin overlying the muscles was prepared by skin prepping paste before placing the electrodes to lower the electrical impedance.

The reference feature space is established by a windows program. The subject can select five motions of head and shoulders that he feels familiar and their recognition ratio is good. The selected motions were usually preserved in individuals with tetraplegia at the C4 level or below.

The correct discrimination rates of three subjects are 86%, 88%, and 93%. The response time of this system is less than 0.3sec. It is not significant here, and the delay is owing to prevent the interference of short-time noises and ECG. The computational delay is within 0.15sec. The recognition ratio can be higher with adequate training to the subject.[4] The subject must take time to be familiar with the system.

The performance of the system is more than recognition ratio in real-world operating. It is compared to a mouse and the mouse key in Windows95. The mouse key controlling the mouse cursor by keyboard is available in Windows95. A testing program creates ten buttons sequentially and computes the time to click ten buttons. The mean times of mouse, mouse key, and the HCI system are 9sec, 66sec, 122sec. And the resolution of this system is not as good as mouse. It is hard to click small buttons.

Conclusion

Applications of the system described here benefit people who can not use the mouse as the input device of PC. CD titles and WWW browser work happily with the subject. This prototype indicates that a DSP-based EMG discrimination system has great opportunity to help human with disability. In the future, many special applications like environmental control system or FES will be implemented on PC. This system will be the input device of patients.

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