Muscleman: Wireless input device for a fighting action game based on the EMG signal and acceleration of the human forearm

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Abstract

In this paper, a new device for human computer interaction, Muscleman, is described. This device acquires the surface Electromyogram of the superficial flexor muscle in the forearm, and the acceleration signal of the forearm's movement. The device can classify hook and straight punch motions of the forearm by analyzing the acceleration data. By analyzing the Electromyogram signal, the force exerted by the user can be measured and used as input signal, even when there is no explicit movement of the forearm, as in the case of isometric muscle contraction.

As a primary application area, we propose an input device for a virtual reality game, in particular a fighting action game. By using this device the user can intuitively make various punching motions, such as a straight punch-like motion or upper cut-like motion. By using muscle contraction as an indication of force the user can intuitively make a special charged attack, such as fireball. Furthermore the muscle fatigue index can be measured and used to give feedback.

To evaluate the developed device a simple command set for the test application has been defined and the algorithm to map the EMG and acceleration signal to the desired input has been developed. The results show that the device can offer the user superior experience when playing the game.

1. Introduction

One of the application areas of virtual reality technology is as an interface for a game. To encourage the feeling of immersion during game play, several interface devices based on virtual reality technology have been developed for each type of game.

Fighting action game is a common genre of both consumer and arcade games. In the typical fighting action game, a player controls the character that represents him or her to until a predetermined level of energy is expended. To provide more fun and strategies, there are usually two styles of attack possible. One is weak attack such as a jab and the other is strong one such as a fireball, which is very common in this genre (see figure 1). To achieve a balance between these, the stronger one should be difficult to use, for example, by adopting complex input sequence, and the strong attack needs more time to recover to the normal state after an attack movement. Therefore, achieving the balance of the attack powers and their accessibility is an important aspect of the game's command interface design.

Common input devices for fighting action games are the joy pad and joystick. These use a stick to move the character and a button to make a certain type of attack, for example, a punch or kick. To make a strong attack the user has to input a complex key sequence that makes that motion difficult to invoke, thereby achieving a balance between two types of attack. Though those devices are cheap and easy to use, they have disadvantages. These interfaces are not intuitive for human fighting movement control, and the user has much to memorize, such as the meaning of the button and the input sequence for a strong attack motion. Moreover, this kind of device cannot deliver the exciting feeling of movement that we usually feel during physical exercise.

Recently developed interfaces have taken more direct approaches to overcome these disadvantages. Users usually make attack movement by punching or kicking themselves and the game interfaces adopt a pad for punch and kick or use an optical solution to detect user movement. These devices can offer a superior feeling of movement without constraint. However, there are still disadvantages. They usually require a predefined booth in which the movement of the user can be detected. In addition, due to relatively expensive hardware, they cannot be used in the home. Though they can make punch or kick attack motion very intuitive, there is no appropriate solution for different skills such as, for example, fireball.

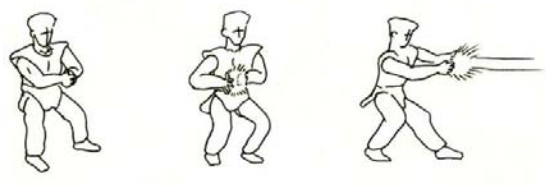


Fig. 1 Typical motion for fireball

In this research, a human-computer interface device designed for a fighting action game, Muscleman, has been developed. The game characters are usually depicted as making an isometric contraction of their arms as an expression of power concentration in order to a make strong attack such as fireball, shown in figure 1. This observation motivated us to develop a new human-computer interaction method using isometric muscle contraction as a sign of concentration for strong attack movement. To measure the force of the isometric muscle contraction, a surface Electromyogram (EMG) was used. Moreover, to obtain more precise information about the user's forearm movement, we installed an accelerometer. By analyzing acceleration data record obtained from the accelerometer, it is possible to know which direction the forearm is moving. Further more the classification of attack movement for example whether the motion was a straight punch motion or an upper cut motion is possible.

Wireless transmission was adopted so as not to disturb the user’s motion. By adopting wireless transmission, the stage of a game can be extended virtually with no limits in space.

This paper is organized as follows. In section 2, we describe the hardware design features. In section 3, to test the developed device we define a simple command set for research purposes, and we discuss the algorithm to map the signal input to that command set. In section 4, we discuss the implemented device's advantages, disadvantages and future research topics.

2. Design features of hardware system

The block diagram of the developed device is shown in figure 2.

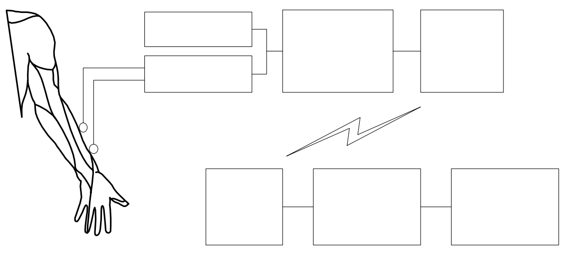


Fig. 2 The block diagram of the device

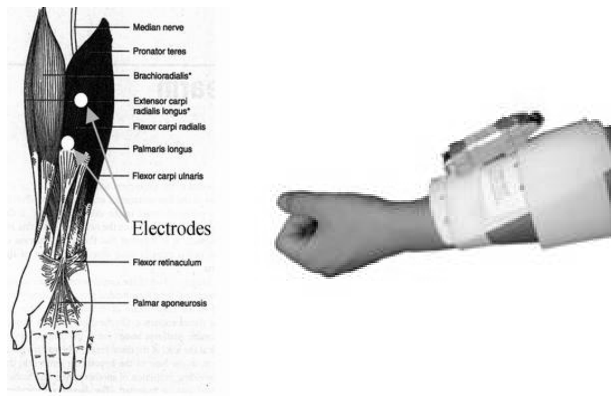
The EMG is the electrical signal produced by the activation of the neurons that sends the contraction signal to the muscle. By measuring the EMG signal, we obtain the following information about the muscle exercise. [1]

- The activation timing of the muscle;
- the force produced by the muscle; and
- an index of the rate at which a muscle fatigues.

Although it is possible to know how the arm is moving by attaching several electrodes at the muscle points where the contractions for movement are generated, it is undesirable for a Human-Computer Interface (HCI) because using many electrodes is generally very inconvenient. Furthermore, the major muscles for a punching motion are located near the shoulder and on the upper arm where clothing is an obstacle to electrode installation. Therefore, we placed the electrode on the forearm, where it is easily applied to most users.

The muscle fatigue index information can be used for designing games more realistically. For example the game character or the avatar which represents a user, can be expressed being tired if the user’s muscle fatigue index exceeds a certain threshold. And the user will not waste his attack movement because the stamina for an ordinary human is limited. Such a feedback is impossible for previous game interfaces.

To decide the exact position where the device and electrode should be installed the following factors were considered. Basically, the electrode should be installed on a large muscle for EMG signal detection and, to measure the acceleration of the forearm correctly, the device should be near the hand. The skin where the EMG signal is acquired should be clean for the ionization process. The hair on the skin can be an impediment to the conduction of the electrical signal. Therefore, the anterior side of the forearm was chosen, as shown in figure 3.



(a) (b)

Fig. 3 (a) The electrode installation site (b) Band type structure

To provide secure contact between the skin and the electrode, we used a band type structure. The electrode is a dry Ag/AgCl electrode without sticky gel. (See figure 3 (b)).

To reduce the motion artifact induced by the capacitance of signal cable, we placed the amplifier module on the back of the electrodes. By using the amplifier on the electrode, the Signal-Noise Ratio (SNR) is improved significantly.

In order to analyze the movement of the forearm completely we installed a three-axis accelerometer. In addition, so as not to disturb natural movement of the forearm, we used wireless transmission for communication between the device and the computer unit.

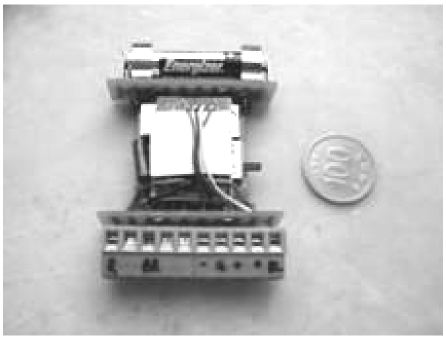


Fig. 4 The developed device

The developed device is shown in figure 4, and the specification for the device is summarized in table 1.

Table 1. The specification of the device

EMG amplifier	
Cut off frequency	30~300 Hz
Gain	30~40dB
Size	20x30 mm
No wire	Reduction of motion artifact
Sampling frequency	450Hz
Accelerometer	
Acceleration Range	-5G ~ +5G
Sampling frequency	150Hz
Channels	3 orthogonal X,Y Z
Output range	0 ~ 5V
Wireless transmission	
Size	15 * 23 mm
Data rate	9600bps
Computer interface	Serial port(RS-232)
Power	One 1.5V AAA battery
Operating range	5 m

3. Test results

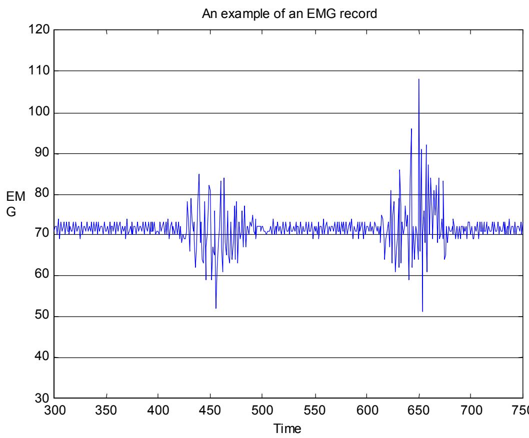
First we have to define the commands that should be generated from the input analog signals of the EMG and the three-axis accelerations.

Here we defined a set of simple commands for research purposes. For one arm, we chose two different punches, upper cut and straight punch, with heavy and light power levels for each type of attack.

Table 2. The test command set

	Light	Heavy
Straight	Jab	Fireball
Upper cut	Light upper cut	Strong upper cut

To measure the force exerted from the EMG the root mean square value of the EMG signal is commonly used. As shown in figure 5, the more power the user generates the higher the RMS value obtained.



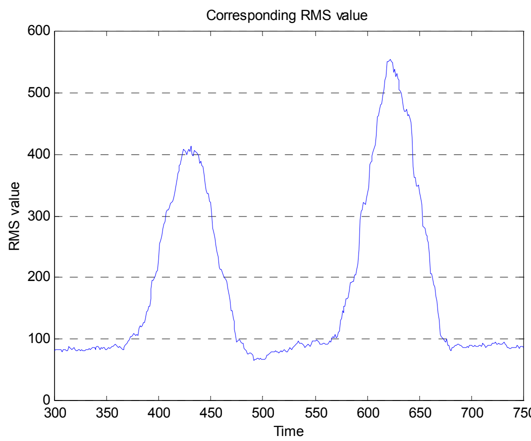


Fig. 5 (a) Typical EMG record
(b) Corresponding RMS value

For the EMG signal is random and the absolute amplitude varies with the every user and condition, an calibration is required. The calibration protocol is defined as follows.

a) Let the user relax and acquire the EMG signal and calculate the RMS value. The RMS value here will be used as the base value. If the RMS value is too high, it means that the contact of the electrode to skin is not secure, so ask the user to check it again.

b) Let the user make isometric contraction of his forearm with the maximum force he can make. The RMS value here will be used as the maximum value.

c) During the game play all RMS value measured will be normalized using the base value and the maximum value.

By using this calibration protocol the fairness can be maintained without dependence to the condition.

We adopted a simple capacitor model for force. As the user makes an isometric contraction of his or her forearm, the gauge is charged. The speed of charging depends on the force produced by the user. The higher the force used, the faster the charging

Using this model, in order to make a strong attack, it takes time to charge the power gauge, thus achieving a balance with light but quick motion. Because the rate of charge depends on user effort, it is a feedback to the user input. Therefore, it can give a greater feeling of immersion.

To classify the upper cut and the straight punch we compared the upper cut acceleration log and the straight punch acceleration log. It was possible to make the classification using only the x-axis information. As can be seen in figure 6, they can be classified using the following logic.

First, the local maximum or minimum, where the first derivative is zero, is located; then if the point's value is above the hook threshold, the movement is a hook motion. If the value is below the straight punch threshold, the movement is straight punch motion.

4. Discussion

The developed device has the following advantages over previous input interfaces. First, with this device the user can make a strong attack very intuitively without learning complex input sequences. The balance in accessibility between weak and strong attack is very straightforward. It takes longer to charge the power level, and the user has to apply more power to make a strong attack. The muscle fatigue index can offer new kinds of feedback which was impossible with the previous input device. The pleasure of physical attack is also maintained.

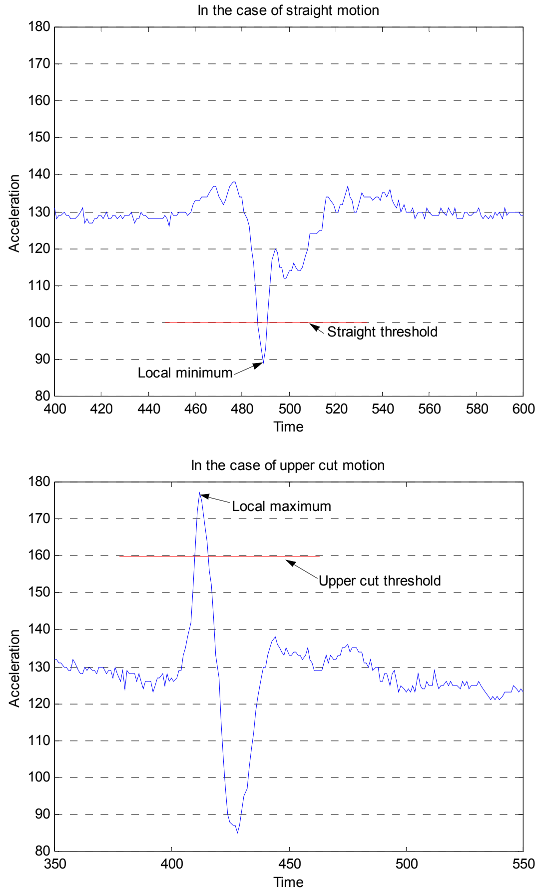


Fig. 6 The Different acceleration records generated by straight punch and uppercut motion

This device is inexpensive, small and is suitable for home use. The feature that it can distinguish between upper cut and straight punch motion of the user forearm is also useful for interface purpose since it allows variations. Because we adopted wireless transmission, this device does not have any constraints on the user's motion within the range.

The disadvantages of this device are as follows: the EMG is a random signal and the amplitude and the signal characteristic is different for different operators and even for same person it changes with time and the skin condition. Stable contact between the electrode and the skin is also another requirement. But many disadvantage can be overcome by adopting simple calibration process.

Here an input device for only one arm was developed but the same concept can be applied to leg motion and the combination of arm and leg motion can yield a more complete interface. However, when designing the interface for the legs, the step information that is moving the character back and forth needs to be considered. This requires more research.

Here, we developed an algorithm to discriminate between upper cut and straight punch motions of the forearm, using only x-axis acceleration. More complicated sets of user motions can be defined and discriminated using other axis information, as required by the specific application. Moreover, a more realistic device can be developed using force feedback. To give the feeling of collision to the forearm, a motor driven vibration can be used. Furthermore, although it will require more research, an electric stimulation may be used. Research of Hiroyuki Kajimoto [2] showed that variations in electric stimulation lead to different tactile sensations.

5. References

[1] C. J. De Luca, "The Use of Surface Electromyography in Biomechanics", Wartenweiler Memorial lecture, The Int. Society for biomechanics) 5 July 1993
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[2] H. Kajimoto, N. Kawakami, T. Maeda and S. Tachi, "Electrocutaneous Display as an Interface to a Virtual Tactile World", Proc. IEEE VR '2000, pp. 289-290. 2000