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Muscle Contraction: The Subtle Way of Human Computer Interaction

[1]Rubana H. Chowdhury, [1]M.B.I. Reaz, [1]A.A.A. Bakar and [2]Md. Sharif Hasan
[1]Department of Electrical, Electronic and Systems Engineering, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
[2]Department of Cardiac Surgery, Ibrahim Cardiac Hospital and Research Institute, 122 Kazi Nazrul Islam Avenue, Shahbag, Dhaka-1000, Bangladesh

Abstract: The advent of new technology has opened opportunities to the computer users to consider alternate ways for humans to interface with machines. Research groups are looking to use computer interfaces that can allow users to communicate with devices in a subtle way and allow virtual reality environments to create an immersing experience. Electromyography based wearable input device can interface with mobile devices in a subtle way. Electromyography can also be used for interactive computer gaming as well as to control flights through virtual joysticks and controllers. This study provides a brief review on various ways for humans electromyography (EMG) signal to interface with machines. Therefore, the crux of this study is to overview the up to date developments and research related to the EMG interface with the wearable devices. This study further opens up a passage for researchers and end users to advocate an excellent understanding of EMG interfacing with mechanical devices.

Keywords: BCI technology, Bluetooth, EMG, EEG, HCI, PDA

INTRODUCTION

To create a new standard it takes something that is not just a little bit different. It takes something that is new and captures people's imagination. The art of our era is not art, but technology. The proper artistic response to digital technology is to embrace it as a new window on everything that is eternally human and to use it with passion, wisdom, fearlessness and joy. Today's notebook computers, Personal Digital Assistant (PDA), mobile phones have more compact screen sizes and decreasing physical dimensions, meanwhile becoming increasingly computational supporting network connectivity. The user interfaces for these devices are generally derived from graphical interfaces for desktop computers using reduced versions of the keyboard and mouse. Computers nowadays are small enough to be worn, which has opened an opportunity to explore new methods for inputting data to computers, portable systems and wearable devices. Electromyography (EMG) is a method of recording the electrical currents generated in a muscle during its contraction (Hussain *et al*., 2007). This EMG technology helps capture gestures as inputs for virtual joysticks, keyboards leading to new applications in mobile computing, video gaming industry along with flight simulation and control (Wheeler *et al*., 2005; Adrian *et al*., 2012; Byung and Hyeok, 2008).

Humans communicate with computers in variety of different ways. The standard way of communicating with a computer is by using a keyboard and a mouse. Over the years, a number of human computer interfaces have been developed such as the light pen, the drawling tablet and speech recognition programs. All of these interfaces require mediation between human and the computer. Most of this mediation is a hardware device that translates movement to a binary number that the computer can process. User Interface is about those aspects of a system that the user comes in contact with; an input language for the user, an output language for the machine and a protocol for interaction. Problems have arisen with controllers like the mouse and the keyboard. Ergonomically incorrect, these pieces of equipment often cause medical problems, such as carpal tunnel syndrome after periods of use. People with disabilities, the very young and the very old have trouble controlling computer interfaces such as the keyboard and the mouse. New human computer interfaces allow the end user to control the computer in a new and exciting ways.

This study provides a brief review on various ways for humans electromyography (EMG) signal to interface with machines. Therefore, the crux of this study is to overview the up to date developments and research related to the EMG interface with the wearable devices. This study further opens up a passage for researchers and end users to advocate an excellent understanding of EMG interfacing with mechanical devices.

Corresponding Author: Rubana H. Chowdhury, Department of Electrical, Electronic and Systems Engineering, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

MATERIALS AND METHODS

Controlling computer using bio-signals: One of the recent technologies enhancing Human Computer Interaction is a bio-signal interface that uses electroencephalographic (EEG) waves oriented in the brain (Asaduzzaman *et al*., 2011; Reaz *et al*., 2007). This is also known as Brain Computer Interface (BCI). Bio-signal interfaces allow controlling a computer by intentionally altering certain signals associated with different bodily functions representing alternative communication channels (Rainer and Torsten, 2008). Neural interfaces fall into two broad classes: invasive and noninvasive varieties. Bio-control systems concentrate on noninvasive interfaces designed for casual wear. The terms bio-signal interface and neural interface refer to a direct data link between the electrical signals generated by the human nervous system and a computer. The basic architecture of a bio-signal interface is illustrated in Fig. 1.

The noninvasive interfaces acquire signals using surface electrodes, which are preprocessed to reduce noise content. Various pattern recognition algorithms operate to actuate the interface, depending on the signal type. By using muscles and nerves under volitional control, users can direct a computer's activities without using conventional button-press devices such as keyboards or mouse. EMG signal is a noninvasive type of bio-signal. Under some considerations, all muscles emit electrical signals that cannot be felt with the normal senses. The EMG signal gives an electrical representation of neuromuscular activation associated with contracting muscle (Reaz *et al*., 2006a). The muscle activity is always controlled by the nervous system.

Wireless acquisition system for surface bio-signal: EMG can be used to sense isometric muscular activity (type of muscular activity that does not translate into movement. This feature makes it possible to define a class of subtle motionless gestures to control interface without being noticed and without disrupting the surrounding environment. The device for this purpose includes a high input impedance amplifier connected to electrodes, an anti-aliasing filter, a microcontroller to sample and process the EMG signal and a Bluetooth communication module to transmit the processing results. When activation is detected, the controller sends a signal wirelessly to the main wearable processing unit, such as mobile phone or PDA. This device is attached to an adjustable elastic band that can be hidden under cloths. Surface electrodes are placed on the skin surface to acquire the signals. This simple controller can be used within a multimodal interface. The system can have a display capable of delivering high-resolution information such as text, as well as delivering low-resolution peripheral cues (that do not require a certain level of attention). Events such as a new message or phone calls generate cues. The user can react to cues by contracting the muscle, for example requesting more information about the event such as the message subject or the caller ID. The peripheral cues can otherwise be ignored, if the user cannot afford to give attention to the computer. Using EMG, the user can react to the cues in a subtle way, without disrupting their environment and without using their hands on the interface. Figure 2 shows EMG as a subtle input interface for mobile computing.

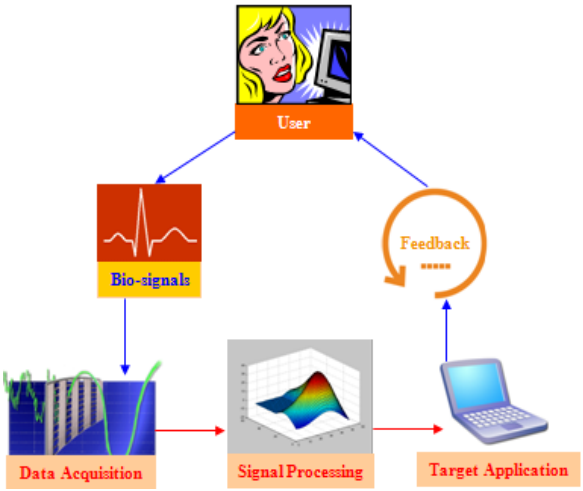

Fig. 1: Basic Architecture of Bio-signal interface

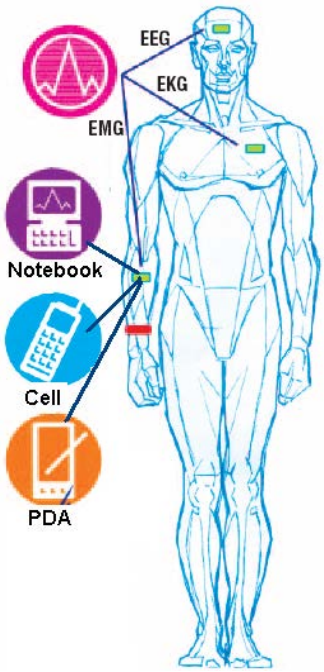

Fig. 2: EMG as a subtle input interface for mobile computing; Vince Stanford, "biosignals offer potential for direct interfaces and health Monitoring

The EMG controller does not occupy the user's hands and does not require them to operate it; hence, it

is "hands free". When combined with eyeglass displays and/or audio output, it forms a closed loop "hands free" system. This can be highly advantageous in various situations, for example, when the user is carrying objects. It can also be useful in specific fields, such as maintenance, where the user's hand are needed to perform a principal task and uses the mobile computing system for assistance. EMG signals acquired controlling computer interfaces can also serve for status monitoring of elderly individuals who wish to live at home but who might occasionally need help. The EMG sensors can transmit their individual data streams, using 2.4 GHz or 900-MHz bands, depending on the application and bandwidth availability, to a wearable PDA that can store, summarize and forward the results (Min *et al*., 2011).

RESULTS AND DISCUSSION

Bio-affective gaming interface: Interactive computer gaming offers another interesting application of bio-signal based interfaces (Reaz *et al*., 2006a; Arroyo-Palacios and Daniela, 2010). The game system would have access to heart rate, galvanic skin response and eye movement signals, so the game could respond to a player's emotional state or guess his or her level of situation awareness by monitoring eye movements. For example, an interactive game character could respond to a user who stares or one who looks around, depending on the circumstances. This use of eye tracking is easier than using the eyes as a precision pointing device, which is difficult because the eyes constantly explore the environment and do not offer a stable reference for a screen pointer. To provide more fun and strategies, there are usually two styles of attack possible in fighting games. One is the weak attack and the other is the strong attack. 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. A human-computer interface device designed for a fighting action game, "Muscleman", has been developed by Park and Kim (2009) in Korea. 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.

To measure the force of the isometric muscle contraction, a surface EMG was used. Moreover, to obtain more precise information about the user's forearm movement, the gaming system is installed with an accelerometer. By analyzing acceleration data record obtained from the accelerometer, it is possible to know which direction the forearm is moving (Reaz *et al*., 2006b; Che-Chang and Yeh-Liang, 2010). Furthermore the classification of attack movement for example whether the motion was a straight punch motion or an uppercut motion is possible. Wireless transmission is 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. Figure 3 shows the system block diagram of "Muscleman".

Bio-signal based interfaces are used in NASA: At the NASA, Arms Research Center at Moffett Field, California, the extension of the Human Senses Group uses bio-control systems interfaces. They have used EMG/EEG signal in their research program on human interfaces to flight systems (Stanford, 2004). The group seeks to advance man-machine interfaces by directly connecting a person to a computer via the human electrical nervous system. Based on EMG and EEG signals, this research applies pattern recognition system to interpret these signals as computer control commands. These NASA researchers have used EMG signal to substitute for mechanical joysticks and keyboards. For example, they developed a method for flying a high-fidelity flight simulator of a transport aircraft using EMG based joystick. Figure 4 shows the flight control using EMG technology. The virtual joystick was actuated through an armband implanted with eight electrodes connected to sensors as the pilot gestures to land the aircraft. The pilot could also make emergency landings of a simulated aircraft that had been damaged. Charles Jorgensen, head of NASA Ames' neuroengineering lab, states that this is a fundamentally new way to communicate with machines. His research group is moving away from the idea of controlling machines with levers and knobs, moving instead toward having machines respond directly to human gestures. In addition to aircraft control, the technology might also help astronauts in bulky space suits to control power tools used to work outside the space vehicle, such as in repair activities or construction. A more ambitious idea for reconfigurable airplanes and other transportation machinery is a virtual wearable cockpit or command center. The US Air Force and other military branches increasingly use unmanned vehicles for surveillance missions. One way to control these systems from the field is a wearable cockpit. One could use a wearable computer with a wireless link and display goggles and then employs EMG-based gestures to manipulate the switches and control sticks necessary for flight (Wheeler and Jorgensen, 2003). Noncontact EMG sensors sewn into the field uniform could then sense movements as the acting pilot pretended to

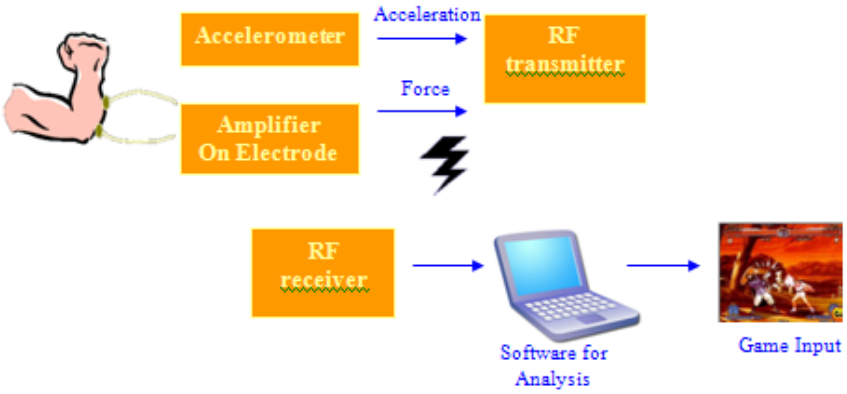

Fig. 3: System block diagram of "Muscleman"

Fig. 4: Flight control using EMG technology; Vince Stanford, "biosignals offer potential for direct interfaces and health monitoring"

manipulate control inputs. A space-based application could let astronauts' type into a computer despite being restricted by a spacesuit. If a depressurization accident occurred on a long-term space mission and astronauts needed to access onboard computers, they could use EMG electrodes in their spacesuits to replicate a computer interface.

A further increase in speed, accuracy and usability is clearly needed before general users of pervasive computing devices adopt these new interfaces based on EMG. In addition, recognition based systems that use the nervous system must be selective about reacting only when the user actually intends to initiate an action, not when he or she is simply performing daily activities. Therefore, BCI technology investigators are looking at how to let users have a brain-controlled switch that allows intermittent control, thus letting them decide when they want to control the system and when to put it into a stable off state while they think about other things. Muscle contraction is a good alternative method, which allows the interaction with a computer by controlling any muscle of one's choice. The detection of a particular muscle contraction for a particular action should be unaffected by other muscle contraction, thus the prospective device needs to be very precise, efficient and robust.

CONCLUSION

Serious researchers are developing practical applications using muscle contraction, especially in the area of interfaces for people with mobility limitations or disability. These will play a significant role in the future. Prototypes are being made on EMG-based mouse and speaker recognition system. The mouse can act both as a mouse and as an alert system for potential ergonomic injuries. When someone is notified of a potentially harmful movement, the system itself conducts a different movement to perform the same action by changing EMG signal mapping to computer commands. This will bring a solution to medical problems caused by the existing ergonomically incorrect HCI designs.

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