A Wearable Sensor Fusion Armband for Simple Motion Control and Selection for Disabled and Non-Disabled Users.

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Abstract—This paper presents the GE-Fusion Band, a wearable prototype armband that incorporates Gyro and EMG sensor fusion for interfacing with technology. The armband enables any user with some level of yaw and pitch arm movement, and arm muscle voluntary contraction, to potentially control an electrical device like a computer, robotic arm, or mobile phone. Simple Gyro data calculates pitch and yaw, while EMG threshold based techniques were used for a virtual enter button. Only light weight signal processing was required to achieve acceptable results, reducing the required processing time on the microcontroller and receiving device, thereby allowing the GE-Fusion Band to be interfaced with almost any device. The device aims to make interaction more intuitive for disabled users while providing an alternative interface for non-disabled users.

I. INTRODUCTION

Electrical devices such as a computer can be connected to a multitude of user interfaces, the most popular interfaces being the mouse and keyboard. However, for disabled users with upper body amputations the answer is slightly different: eye tracking, perhaps computer vision, or more commonly using a keyboard and mouse with or without their prostheses. Most prosthesis can be big, bulky and tiring to continually use, a simple, intuitive, and compact interface would be ideally suited for the disabled. Interfaces that can reduce the gap between disabled and non-disabled users would improve productivity and reduce the stigma associated with hiring a less physically enabled individual.

Most design approaches usually focus along the lines of muscle and brain interfaces, however neither approach is developed enough to provide a simple, easy to use, multiuser compatible interface, as the majority require training and calibration, typical too complex and time consuming for a user. Hence, systems which minimize these complexities are predicted to be best suited to wide spread use.

New portable interfaces appear all the time, for example, 6th sense[11], designed by Pranav Mistry combines computer vision with a portable computer and projector, turning any surface into a display and uses finger location with gesture control as input. Microsofts design of Skinput[1], an acoustic based device combined with a mini projector, measures the complex sounds generated from finger presses on a users arm, converting any part of your arm into a usable interface. Both approaches provide tremendous potential for individuals, but as with most approaches are not necessarily focused on the disabled.

Procedures such as nerve reinervation[8], or even electronic nerve connection[13], can restore a lot of lost functionality into a prothesis, however not every individual is able, or wants to perform such a procedure. Alternative approaches at interfaces for the disabled include: voice control mouse, accelerometer mouse, eye tracking computer vision interface, and gyro mouse control, just to name a few. However, each will have its own limitations, although, sensor fusion has been proven to compensate for the majority of the negative effects.

We describe in this paper, an input device that can be used by any individual who has some level of arm movement and arm voluntary muscle contraction control. The device is called a GE-Fusion Band (Figure 1), as it fuses together, Gyro and EMG sensors to form a synergy. It has many potential applications, and is designed to be simple to build and easy to use.

The remainder of the paper includes: Section II - Background, III - Design of the Fusion Band, IV - Discussion and V - Conclusion and Future work.

Fig. 1. Fusion Band with Electrodes
II. BACKGROUND

Motion devices such as gyros and accelerometers, which measure rate of rotation and acceleration respectively, are limited in their 'hands free' capabilities, these are able to detect motion, but are limited in their ability to perform a selection, or act as virtual enter button. There are inventive solutions for bypassing the limitation, for example finger click selection used with an accelerometer, uses an individual's ability to click their fingers to act as a mouse click [5], however not everyone can click their fingers, alternatively Eom et al used a gyro with a quick-nodding action to act as a mouse click[3], however this could generate false positives, therefore neither are ideal solutions.

EMG, which stands for Electromyography, measures a very small electrically potential (in mV) produced during muscle activation. It would be ideally suited to act as a virtual enter button, a simple clench of the fist, or movement of a finger could be utilized.

EMG alone can perform the full task for both motion and selection as shown from applications ranging from wheel chair control[19], robotic hands[7], and control of virtual games and simulators[15]. Monitoring one's muscles could potentially allow us to recreate the exact motions and force of a human, however current technology limitations prevent us from fully unlocking its potential.

Accelerometer’s and gyro’s are currently better at measuring motion than EMG. Although EMG can be used for an all in one recognition system, simple and intuitive gestures would likely require a number of electrodes, being potentially difficult to position, would require significant signal processing, while also being overly complex for most users, especially non experts. These reasons motivate researchers to combine sensors to simplify the control process.

Relatively few devices exist that combine both motion and EMG sensors, there are examples of accelerometer motion sensors [16], Gyro sensing [3], and even some level of limited control using EMG [10]. However by combining sensors, control can be improved, such as combining Accelerometer and Gyro for Motion Analysis [4], or combining Accelerometer and EMG sensors for sign language recognition [18] and Virtual Game Control [20].

One of the largest challenges faced using EMG with a portable sensor fusion system, is the complexity of the sensor design. Currently relatively low cost, portable, and user friendly EMG systems are generally not available. The closest example is Saponas et al illustration of a portable EMG armband[12]. A simple EMG implementation would allow the device to securely attached to the user.

Fig. 2. Hardware Flow Chart

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To simplify the EMG development process, an ultra simple EMG circuit was constructed using the INA128 Instrumentation Amplifier (IA). An IA amplifies differential inputs and subtracts the common mode signal, which causes noise presented on both channels to be partially suppressed. The simplified EMG circuit uses a capacitors reactive impedance attached to the IA gain pins, setting a variable frequency dependant gain, thereby only amplifying important frequencies and thus creating a high pass filter. The capacitors impedance(which is inversely proportional to the IA amplification) is calculated from equation (1), and an example is shown in figure 3.

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Impedance = \frac{1}{(2 \pi FC)}
\]  

The EMG sensor requires 3 electrodes attached to the negative and positive terminal of the IA with a 3rd electrode attached to ground. The electrodes were 30mm diameter
Fig. 3. Reactive Impedance Graph - Impedance is inversely proportional to amplification

Fig. 4. Natural Arm Movement

One of the problems associated with surface EMG, is the electrodes require good contact in order to achieve a reasonable signal. However, Trejo et al [9] and chi et al [17] have created non-contact electrodes that can detect biosignals, like EMG, through clothing which could make EMG technology more wearable, or even infuse with clothing, so that minimal user input is required.

Fig. 5. Fusion Band Freedom of Motion

Although drift is still a problem with the device, there are potential compensationary methods. For one, gyro activation only during user activated EMG would allow the user to automatically compensate for drift, however this limits the fusion bands selection capabilities. The another approach is to have a fixed work space like a computer screen and use relative control, this would allow the user to make adjustments to a pointers position similarly to when you continue to move your mouse out of the screen boundary, which causes an offset. Therefore using the window boundaries a user can adjust offsets relatively easily.

IV. DISCUSSION

A gyro was chosen over other sensors, as it most naturally follows human arm motion. Figure 4 demonstrates the human arm joints with available motion. As can be realized, the natural motions include yaw, pitch and roll. Horizontal and vertical movements require multiple joints to work in unison, thus requiring addition energy expenditure. Using pitch and yaw uses well developed muscles used in everyday life, thus minimizes muscle fatigue, and allowing a user to use the fusion band for longer periods.

The fusion band has the majority of hardware inclosed in a small area, even the electrodes can be worn underneath the armband, making the interface relatively small and easy to use, even for non-experts.

A gyro outputs the rate of rotation in degrees per second, which is linear, and hence does not require significant processing.

The Fusion band uses the L3G4200D low voltage Gyro, which provides selectable 250/500/2000 degrees per second scales, at a 16bit precision, while not being overly expensive. The gyro communicates over a I2C link to a microcontroller, while the EMG sensor is sampled from an onboard ADC. Data is transmitted from the microcontroller serial port to the computer via the FTDI FT23RL USB to serial integrated circuit. The use of a Arduino board simplifies and speeds up the design process, allowing for faster development times. Although limited in its code efficiency, it provides an excellent prototyping structure. The variety of sizes and speeds allows a tailor made design.

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There are certain limitations with using EMG on the wrist, for one, rotation of the wrist will effect the EMG signal causing a false positive, thus the reason yaw and pitch are used. Smaller, more selective electrodes would improve the interaction, plus machine learning might be able to extract further usable information. Roll could potentially be useable at other locations on the arm, where muscles not linked with
roll activity are present.

The Majority of the Gyro and EMG signal processing is performed on the microcontroller, this includes the acquisition, and partial processing. The receiving device only performs moving average functionality. This greatly free up the receiving device processing time, potentially allowing the devices to work with a vast majority of devices (Portable and fixed).

To use the fusion band a portion of the arm must be movable in the yaw and pitch orientations i.e. up/down and left/right around a central point (As shown in figure 5). Any muscle adjacent to the fusion band can be used to generate an EMG signal to control the virtual enter button, therefor this device is not suitable for paralyzed individuals.

The Fusion Band prototype, was designed from off the shelf parts. The Arduino Pro mini is limited in processing power and code efficiency, however it makes up for it with its small footprint, and ease of use. Attempting to use further sensors to improve the device or including complex signal processing is likely to need an improved microcontroller.

The fusion band jumps the gap from simple mouse controller to general user interface. The uniqueness comes from being able to use the device on or off a table, sitting or standing. It is light weight, easily portable, and can interface with any device that requires human interaction. Applications could include but are not limited to, control of mobile phone, interfacing with an electronic wheel chair, control of a computer mouse, 3d object manipulation, virtual reality, robot control, robotic arm control, virtual witting, virtual signature used for interfacing with an electronic wheel chair, control of a computer with any device that requires human interaction. Applications sitting. It is light weight, easily portable, and can interface is likely to need an improved microcontroller.

V. CONCLUSION AND FUTURE WORK

The contributions of this paper include confirming the feasibility of designing a gyro motion controller, along with an ultra simple EMG circuit, to create a sensor fusion armband for both disabled and non-disabled users. The simplicity of the design potentially allows other researchers to easily integrate each or both approach's in their own work.

The Fusion Band is a step towards making a human computer interface for disabled and non-disabled users. The device aims to make interaction more intuitive for disabled users while providing an alternative interface for non-disabled users. The Fusion Band provides an alternative method for controlling your computer pointer and can be used in conjunction with an on screen keyboard to provide complete user interaction.

Future work involves correcting the inherent drift issue with the gyro, which can be compensated with further sensors, such as an accelerometer and magnetometer. The Fusion Band currently communicates to a computer via FTDI FT232RL USB to serial integrated circuit, which also powers the device. Future plans involve making the device entirely wireless.

Additional features such as voice recognition would enhance the interaction, plus a small speaker could be used to provide feedback to the user. The Fusion Band is ideally suited to work with small devices, where a physical user interface is difficult to implement, for example: interfacing with a wearable visor/glasses based display. The addition of further EMG channels would increase the number of potential applications. When combined with the motion sensing fusion, could provide a rich user interface to control devices.

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