Muscle Tremor as an Input Mechanism

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ABSTRACT
We present the use of human physiological tremor, detected by a linear accelerometer, as a novel form of input for mobile devices. This allows the device to be aware if it is being held in a human hand, and in which posture. It also has security applications, as human tremor characteristics are individual. We describe two simple demonstrations of the use of tremor. One demo uses isometric muscle tremor as a proxy for a pressure sensor, and allows a user to 'pump up' an onscreen balloon. The second demo simulates a mobile phone application, using muscle tremor to enable the device to be aware if it is currently held by human hand, and to stop ringing when picked up.

Additional Keywords and Phrases: muscle tremor, accelerometer, input mechanism, pocket PC

INTRODUCTION
We incorporate the use of muscle tremor into the design of a user interface. This can potentially be used in a number of ways, from owner identification, knowing that a device is currently held in the user's hand, to a proxy for pressure sensing, via detection of isometric tremor. To our knowledge this is the first study, which attempts to utilise muscle tremor as a form of input. In the past, physiological tremor has largely been treated as an annoyance and filtered from input devices such as joysticks and surgical tools. Other work has focused on diagnosis of pathological tremor.

Mobile devices are widely used for a variety of everyday tasks. However, with significant spatial limitations and the requirement for a small screen and small buttons, interacting with these devices can often prove to be difficult. This has led to the development of mobile devices instrumented with sensors, which are designed to aid more natural and less obtrusive forms of interaction. These sensors can range from touch sensors for detecting if the user is holding the device, accelerometers for sensing the inclination of the device, to infrared sensors for detecting proximity [1]. Price and space pressures tend to act against adding surplus sensors to a handheld device. We describe how any device with an existing accelerometer, can utilise human tremor to enhance its capabilities, and potentially replace other sensors, such as proximity and pressure sensors.

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MUSCLE TREMOR
'Muscle Tremor' is present in everyone. In fact oscillatory behaviour is a common form of normal biological function and is described by Beuter *et al.* [2] as "an approximately rhythmical movement of a body part". The aspect of muscle tremor we wish to exploit is often referred to as a person's 'physiological tremor', which is part of a category of tremor referred to as 'postural tremor'. The investigation of muscle tremor can be very complex and there are many differing forms of tremor studied. There are two main classifications of tremor in use. The first is based on the state activity of a body part when tremor is observed and the second is based on the etiology of an underlying disease or condition [2]. The classification of tremor by state activity includes: [4, 3]

- Rest Tremor occurring when relevant muscles are not activated and the body part is fully supported against gravity.
- Action Tremor occurring when relevant muscles are activated, which includes postural, kinetic, isometric, intention, and task-specific tremors.

For the purposes of this study we are principally interested in the 'Action Tremor' category and more specifically in isometric tremor which occurs when a voluntary muscle activity is opposed by a rigid stationary object. There are two separate oscillatory components apparent in 'normal' physiological tremor. The first component is produced by the physiology of the arm and has a frequency determined by the mass and stiffness of a persons limb. This is due to the passive mechanical properties of body parts that are a source of oscillation when they are perturbed by external or internal forces. The second component of muscle tremor is referred to as the 8 to 12Hz component. As opposed to the first component, the 8-12Hz component is resistant to frequency changes. Its amplitude, however, can be modified by manipulating limb mechanics and it is this characteristic of muscle tremor that we wish to incorporate into our interfaces [2].

EXPERIMENTAL SETUP
Our experimental setup consisted of an HP iPAQ 5550, instrumented with a three degree of freedom Xsens P^3C linear accelerometer sampling at 100Hz. Data was logged for various static arm/body postures, and for dynamic arm and wrist movements, in order for us to analyse the variability of the characteristics of the measured muscle tremor.

SIGNAL PROCESSING
Accelerometer logs were imported into Matlab for analysis. Power spectra were produced for each log, using the absolute values of a Hanning-windowed Fast Fourier Trans-

form (FFT). Figure 1 allows us to compare the difference between the $\log_{10}$ power spectra when the pocket PC is (a) held loosely in the hand and (b) when the pocket PC is given a sharp squeeze. Figure 1(a) displays some slight activity in the 8-12Hz normal muscle tremor range, as expected, but this rises significantly when the pocket PC is squeezed and it is this difference which is exploited in our pressure proxy interface, ‘Easy Squeezy’.

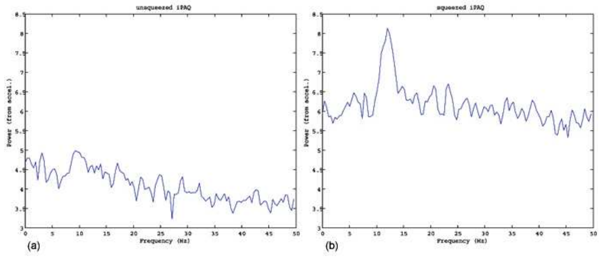

Figure 1: log10 power spectra for an unsqueezed pocket PC (a) and a squeezed pocket PC (b).

DEMOS

Two exploratory demos were produced that exploit the user’s isometric muscle tremor. Demo 1 uses a user’s rest muscle tremor as an indicator that the device is in a human hand and demo 2 uses muscle tremor as an input mechanism to inflate a balloon on screen.

Demo 1: Pick Me Up

The first demo exploits a user’s muscle tremor, enabling the device to be more context aware i.e. to allow the device to recognise when it is held by a human hand. When the application is started the user is asked to hold the device in hand for a few seconds while the tremor in that user’s arm is determined. The characteristic spectrum of this ‘base level’ tremor can then be used to determine if the device is ‘in hand’. When the device is placed on a table it will ring until lifted by the user since the characteristic spectrum of the users tremor will appear in the power spectrum again. The basic movement of the device is not sufficient as an indicator that the device is ‘in hand’, since the device may well be carried in a bag or jacket with no characteristic tremor spectrum present. In fact, if a different user picks up the phone it will not necessarily stop ringing, as the tremor characteristics vary among individuals.

Figure 2: (a) The pocket PC requests that the user hold it. (b) The pocket PC has now measured the user’s rest tremor.

Demo 2: Easy Squeezy

The second demo exploits a user’s isometric muscle tremor to inflate a balloon shown on screen. When the application is started the user is asked to squeeze the pocket PC and this is then used as the ‘calibration squeeze’ for the rest of the program. This calibration is required since different users tend to display varying levels of muscle tremor. Once this is recorded a small balloon appears on screen, which the user can inflate by squeezing the device. A stronger squeeze (stronger than the calibration squeeze) will inflate the balloon to a greater degree than a weaker squeeze.

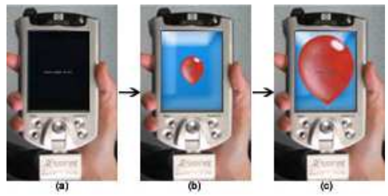

Figure 3: (a) The pocket PC asks to be squeezed. (b) This initial squeeze is measured and the program begins. (c) The balloon can be inflated by successive squeezes of the pocket PC.

CONCLUSIONS AND OUTLOOK

We have demonstrated that it is possible to use physiological tremor in interface design in a positive manner, as an important input mechanism, and that it is possible to provide this added functionality using only a single 3 degree of freedom accelerometer. Other possible applications of muscle tremor range from security applications, such as owner identification, to a proxy for pressure measurements. This would eliminate the need for extra pressure sensors and would make make extremely interesting areas for future study. There are also potential applications for muscle tremor to posture recognition, since differing postures display varying postural tremor because different muscle groups are active, and are under varying loads. This information could also be used in the design of interfaces for mobile devices to make the devices more context aware and opens up a wide range of research opportunities.

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