Initial Design of a Software-Based, Tremor-Reduction, Presentation Pointer

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Abstract – *A significant portion of the population will at some point experience some form of hand tremor. These widely occurring hand tremors can range from barely perceptible, miniscule, rhythmic hand vibrations to large, spontaneous and virtually debilitating hand shaking. Recent hardware and software technological advances have lead to new computer input devices being available to accommodate general human-computer interaction needs. These new technologies also can be adapted to assist those with tremors. One area where a tremor can be particularly frustrating for some is when making a presentation using a laser pointer. This paper focuses on a software-based method for reducing the effect of tremors on computer users who are making presentations. Previous research in tremor reduction techniques is presented and used to motive the design of a software-hardware solution that combines a Nintendo® Wii™ game system controller with customized software. The design of our system is discussed and future directions for exploration are given.*

Keywords: Hand Tremors, Algorithms, Parkinson's, Input Devices.

1 Introduction

Technology continues to evolve at an astounding rate. As is obvious, this also significantly pertains to the topic of computing. This ongoing evolution produces benefits such as improved computer performance, increased user efficiency in completing tasks and innovative methods for human-computer interaction and user interfaces. Of importance is leveraging advancements in technology to improve access to computers and assist with their use by users with various disabilities. Technology continues to advance and provide access to computers and assistance with their use by persons who are blind, deaf, or with cognitive or functional disabilities. Researchers in the area of rehabilitation engineering and assistive technology routinely assess new human-computer interface technology and create innovative uses that can provide needed access to the populations they serve.

One particular example of recent research into assistive applications of technological advances focuses on reducing the effects of hand tremors. A hand tremor is a condition frequently correlated with factors such as advancing age, mental or physical, and a variety of other related pathological and physiological conditions including Essential Tremor and Parkinson's disease [1]. For many with tremor, its impact is minor and little adaptation is needed. For moderate and severe cases of tremor, regardless of the cause, reducing the impact of the tremor is an important quality of life goal, although it can pose a significant challenge to accomplish. Due to relatively recent advances in hardware power, interface devices and software techniques, the implementation of alternative interaction schemes to accommodate to those with disabilities is an active one. For example, a pilot study that explored mouse-motion smoothing techniques for computer users with a tremor shows significant promise [2]. Preliminary work in the area provides a foundation on which to build, and supports the need for innovative re-use of interface devices and software to provide access to computer users with varying degrees of tremor.

In the case of hand tremors, while most slight hand jitters for practical purposes are nearly insignificant as they effect the performance of common, daily routines, other user interface devices are more challenging to use and may require additional effort to use adequately, if they can be used at all. An example of a device that is difficult for a user with a tremor to use adequately is a pointing device, such as a mouse, light pen or laser pointers, which either are simulated in software or are of the hand-held, battery-powered type. Such pointing devices enable the user to interact with a computer by using the intuitive motion of pointing at the some part of the computer screen in order to move the cursor to that location or perform some other pointing and selecting task. This natural and direct interaction can be challenging for a user with a hand tremor as the shake induced by the tremor reduces pointing accuracy and therefore user efficiency, and in some cases leads to increased tremor due to performance-stress, nervousness, frustration and even embarrassment, however unwarranted.

Numerous results have been reported that attempt to address aspects of adapting technology to accommodate users with tremor. Some research focuses on measurement and problem characterization, such as analyzing the relationship between pointing accuracy and distance from the screen being pointed to [7]. Other research has focused on computational and digital signal processing algorithms that are perform mathematical analysis and calculation on pointer position and movement data, and attempt to analyze and react to user needs in order to provide smooth, responsive pointing motion. Notably, the “adaptive gain” method continually reacts and responds to user interaction with the device itself, and has successfully shown that the technique can “decide” whether or not a dampening of cursor or pointer movement in necessary and would be beneficial [4,6]. This adaptive gain technique shows promise as a foundation for solving a wide variety of motion-related filtering problems within the field of human-computer interaction, and appears to be particularly appropriate to tremor reduction of pointer motion.

In this paper, background information on hand tremor is presented and various software and digital signal processing techniques that have been developed to reduce the effect of hand tremor are reviewed. Next, the design of a software-based tremor reduction prototype is introduced and its effectiveness is discussed. Finally, future directions for continued development of this software technique are presented and a number of related projects and applications of this technique and software are provided.

2 Hand Tremor

The term “tremor” is defined as an involuntary shaking movement that is most often noticeable in hands but can also affect other parts of the body including the head or voice [9]. In this paper, the focus is on tremor that impact hand movement. Symptoms of hand tremor may include slight to severe shaking of the hand, which can be caused by several medical or psychological conditions. More specifically, a tremor is an involuntary, sometimes rhythmic, muscle contraction and relaxation that creates an undulating movement pattern within the effected body part. There are benign and natural tremors that occur in the hand with no real underlying cause and they are generally minor in significance. There are also tremors that occur only during certain activities and these are generally minor tremors. The condition known as Essential Tremor is one that typically occurs in people over the age of about 65. An Essential Tremor is naturally occurring, is not normally debilitating, and is not associated with any medical illness or condition. It is believe to be caused, at least in part, by the tendency for muscle weakness gradually to increase with advancing age. Essential Tremor, though typically not dire or debilitating, can still be a major frustration, and this can be particularly noticeable in more public situations such as when using a laser pointer while making a presentation. [9]

More severe tremors are frequently the result of a more serious medical condition. These severe tremors can be a symptom or by-product of diagnosed medical disorders, and there exist several other medical conditions that can cause tremors in a person, as well. Tremors are often recognized as a symptom of mental disorders in parts of the brain, which manage muscle simulation and motion throughout the body, or in specific areas, such as the hands. Examples of neurological conditions that can cause tremor include multiple sclerosis, stroke, traumatic brain injury, chronic kidney disease, as well as neurodegenerative diseases such as Parkinson’s disease. Characteristics of tremor can include rhythmic shaking in an area of the body, difficulty writing or drawing, or even problems holding and controlling utensils. While these are the most common causes, there is a significant variety of types of tremors that affect the body in varying ways and to differing degrees. As with Essential Tremor, more severe tremors also can negatively impact a person with a tremor from being comfortable when in public situations, such as when making a presentation while using a pointing device. [9]

3 Tremor Reduction Techniques

While tremor can be a barrier to a person being comfortable or effective in public situations where the tremor is most noticeable as when giving a presentation, significant research has been done in the area of tremor reduction. [2-6]

3.1 Mouse Motion Smoothing

Research in the form of a pilot study on the effects of a smoothing approach on the usability of a computer by users with Essential Tremor restricted its examination to techniques for tremor reduction when using a common mouse input device [2]. The experiments conducted for this research were human-oriented, allowing for people with differing levels of tremor intensity to participate. These participants were asked to perform various tasks, using a specialized mouse, ranging from target clicking, i.e., clicking on buttons in a specific order, to holding the mouse over a target area for a given amount of time. After the participant had completed the testing, they were given a survey to express their opinions on ease of use of the specialized mouse. This mouse-based approach provides an important starting point in development of a more generalize technique that can apply to our software-based laser pointer approach. The need for user testing is crucial, and led to our desire to conduct preliminary, ad hoc experiments on our software approach as it was developed.

3.2 Adaptive Gain

The paper, "Toward Goldilocks' pointing device: determining a 'just right' gain setting for users with physical impairments" [4] focuses on tremor reduction through the use of personalized gain settings when using computing pointing devices. The authors examined the Adaptive Gain algorithm, a method of analyzing movement patterns and delivering a personalized setting of sensitivity for each individual user. Through this method's use, one can create a significant improvement in pointer accuracy. This paper presented the definition of gain as the proportional difference between cursor movement and actual physical movement, a concept that we draw upon heavily in our prototype design and implementation, and forms the basis for our experimental design. The adaptive gain method reported in this paper can enable pointing devices to reduce how tremors are read by the device and how the cursor reacts on screen. [4]

3.3 Adaptive Calibration and Pointing

In research into an adaptive pointing technique that uses a gain adaptation approach to intuit filtering of pointing device motion, the authors examined the effectiveness of adaptive gain adjustment in general. Adaptive gain adjustment means that the pointing device automatically adjusts the gain, or reactivity, of the device on the fly based on positional data and velocity of pointer motion. The benefit of this approach is that it does not require calibration. Rather, this adaptive technique automatically adjusts based on the presenter's movements. This research builds upon other work in Adaptive Gain, and presents a strong case for incorporating an adaptive approach into the design of our solution, reinforcing how this approach can be an effective and exceptional method in support of software-based tremor reduction. This research also discussed three related approaches to tremor reduction that preceded the Adaptive Gain method. These three methods are target-oriented, manual-switching, and velocity-oriented. These methods are described in-detail in a later section of our paper. Their research also mentioned a Wii-based application that could be used as an inexpensive alternative to the more expensive medical based methods. This idea of using the Wii for testing became an invaluable part of our work. [6]

As previously mentioned, many attempts have been made to increase both efficiency and accuracy when computing with pointing devices. Many of these schemes can be classified under three distinct categories of approaching the problem:

- Target-Oriented Approach
- Manual-Switching Approach
- Velocity-Oriented Approach

These each are examples of pertinent approaches on which more sophisticated tremor reduction techniques can be built. Each of these methodologies pertains to a particular set of actions to which the method is beneficially. The upsides, as well as corresponding drawbacks to each of these approaches are discussed here, providing a foundation for further refinement of our prototype system.

3.3.1 Target-Oriented Approach

The Target-Oriented Approach is associated with a focus on computing "targets" or hotspots. This approach takes popular points of user interaction into consideration when proposing a solution. These points include general point-and-click interaction routines including that of buttons, hyperlinks, and menus. The proposed solution is as the cursor passes near or over these objects, they become "sticky" in response. Sticky, of course, refers to the reduction in the level of apparent on-screen reaction to physical motion. A cursor within the vicinity of a clickable object will adjust its position automatically to stay within its boundaries. Variations of this technique exist in which the cursor responds to objects of interest by dampening the proportion of on-screen motion to device movement.

The Target-Oriented Approach proves a vast improvement in efficiency for most mundane computing tasks. These tasks often associated with basic operating system manipulation, e.g., clicking buttons, file directories, icons, and adjusting control panel options. These tasks become little to no challenge as the technique reduces the duration of time spent on accurate position readjustments.

When applied to other forms of interaction, this technique falls short of user necessities. This applies especially to the dilemma of presentation pointing. There exist no hotspots to which the cursor may "snap." More complex tasks, such as highlighting key points in text and posting drawn lines become difficult, if not impossible. These tasks require line smoothing from the commencement of the physical stroke up towards the end. Furthermore, this technique does not compensate for individual user needs, but rather provides a more general solution.

3.3.2 Manual-Switching Approach

Manual-switching primarily refers to the ability of the user to select the amount of tremor reduction he or she needs at a given point in time. Such a method presents a choice between two fundamental corrective schemas: the absolute and relative approaches. The absolute approach represents a direct relationship between devices manipulation and on-screen cursor position. A pointer directed at a particular spot on a screen will inevitably force the screen to display the cursor at that precise location. In contrast, the relative scheme adjusts this proportion of physical and apparent movement. As an example, a user may decide to use a relative approach. In doing so, the on-screen cursor only reacts slightly to more extravagant motions of the hand.

Both of these approaches are appropriate in particular settings. Allowing users to select between these two approaches provides the opportunity to assist oneself during difficult maneuvers. Furthermore, when one requires swift, vague motions, the option for an absolute movement scheme remains available. It is assumed that the user may determine a "correct" setting which does not need to be modified at too great an extent.

However, it is not always optimal to relinquish control to users. Find an optimal or "best" movement translation setting may not always possible. Needs change due to many unknown variables. Increase in stress levels or change in temperature may serve to heighten the intensity of tremors for example. Factors, such as traversing a stage while giving a presentation, modify the distance between the user and screen. This further increases the potential for on-screen jitters. In other words, changes in environmental influences make the task of decision-making entirely more difficult for the user. The level of cognitive involvement is not beneficial when the mind is already strained and an inefficient environment is generated.

3.3.3 Velocity-Oriented Approach

One term, which has been commonly integrated with this discussion, is the concept of "adaptation." The two major deficits in both approaches hint at the need for a far better, more intricate solution. Target-Oriented approaches present us with the problem of strict, singular behavior for all circumstances. Manual-Switching approaches allow more room for user error, although they can present additional challenges and complexity to the implementation. Regardless, adaptation becomes key as both previous schemes are lacking this capability.

Thus, we come to the Velocity-Oriented Approach. This approach intends to address the two above issues simultaneously by introducing a more universally applicable concept. Velocity-Oriented schemes rely on movement speed analysis to determine what sort of "gain" is required at the present time. Gain specifically refers to the particular proportion of hand speed motion to pointer display reaction distance. Much like the aforementioned relative scheme, gain represents the dampening or intensifying of user input on screen. This technique is simple in that it relies on a simple principle: the higher the velocity of the pointer motion, the lesser the degree of accuracy required to follow through with the motion.

Simply put, this technique represents a concrete foundation for tremor reduction in complex motion schemes. As a whole, the velocity-oriented approach is the first step in the adaptive "evolution" process of software. In other words, the software evolves as the user utilizes the software by responding to stimuli: in this case, velocity. [4]

The only real problematic circumstances involved with the velocity-oriented approach are those with significant lag times or "latency". Latency, that is the duration of time necessary to compute and modify the cursor coordinates, is particularly significant when implementing a velocity-oriented approach. The more time spent modifying input, the more distracting and difficult the algorithm becomes when fully utilized.

These papers all touch on a primary theory called Fitts' Law. Fitts' Law states that the time necessary to move to a location is proportional to the distance travelled along with the size of the target location.[3,5] This law directly impacts tremor reduction research when it comes to large movements made by the presenter. One major issue that has to be addressed in any attempt to reduce tremors is that of lag. Assigning a computer to make adjustments to the cursor position as the presenter moves the pointing device can cause it to lag as it performs adjustment calculations. This lag can become a hindrance to any presentation and could cause any method or technology for tremor reduction to be too much of a hassle for efficient utilization. We attempted to take all of this into consideration during our research.

The adaptive gain technique is a form of the Velocity-Oriented Approach as it is based on the principle of analyzing velocity patterns before adapting to user input. This scheme considers each user as an individual with unique needs. These needs are subject to change with various external inputs. In this sense, an adaptive gain approach would continuously analyze user input and determine an amount of gain sufficient to stabilize the cursor in different situations. In this sense, users are less of a generalization and more of a collection of individual profiles. [4,8]

The adaptive gain approach is beneficial to those who require the most assistance. That said, users with moderate to severe hand tremors of various motion patterns will profit the most from such a scheme. This is mostly due to the propensity of adaptive gain software to accurately respond to most any situation. As tremor intensity increases, adaptive gain software adapts by decreasing the motion sensitivity. In this way, the software eliminates smaller vibrations while dampening more erratic shakes. It is this adaptive nature that makes the adaptive gain approach particularly attractive.

4 Prototype Tremor Reduction System

In this paper, a variety of background is provided on tremor and on the most recent advancements in algorithmic technique of tremor reduction. In order to implement a solution to tremor reduction, a software-based tool was created that enables a user with tremor to make use of a simulated laser pointer device while making a PowerPoint type presentation.

4.1 Software Foundation

To develop a software platform for experimentation with tremor reduction and digital signal processing techniques, an existing open source project was identified that provides a Nintendo Wii-based mechanism for simulating a laser pointer on a presentation screen (Figure 1). The software is called "Wiimote Presenter" and is implemented in the C# programming language. [10]

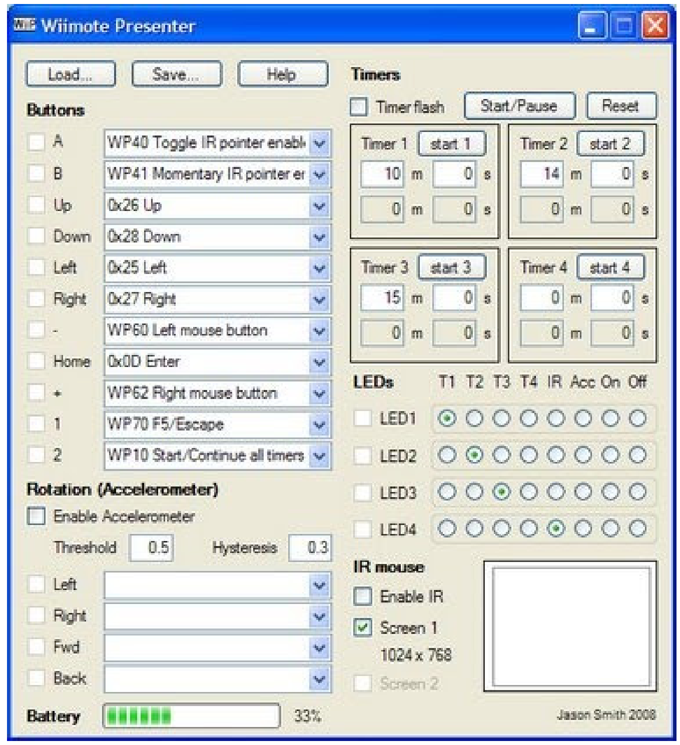

Figure 1. Wiimote Presenter screen.

The Wiimote Presenter software was modified to incorporate a variety of movement filtering algorithms. Variations of the adaptive gain technique seemed to be most effective, although evaluation of techniques was a secondary goal at this point, the production of a viable research platform for experimentation of these techniques being the primary goal.

4.2 Prototype System Cost

For the system being produced ultimately to be useful to any user, it is desired to consider cost to that user. It is assumed that the user owns or has access to a computer and projection equipment, so those costs are not included in the estimate. In order to use the modified Wiimote Presenter software (free), a Wiimote remote control device (Figure 2, $24 US) a Bluetooth adapter and receiver (Figure 3, $16 US) are needed. Thus, the overall investment in a working, tremor-reduction solution is about $40 US, which is relatively affordable.

Figure 2. Nintendo® Wii™ Controller.

Figure 3. Bluetooth USB adapter.

4.3 Filtering Example

Although the prototype software is under active development, preliminary results showing the visual impact of tremor reduction algorithms are encouraging. To characterize the effect of various tremor reduction approaches, the current technique is to gather descriptions of subjective observations of the effect. The goal of filter is illustrated in a before and after diagram (Figure 4).

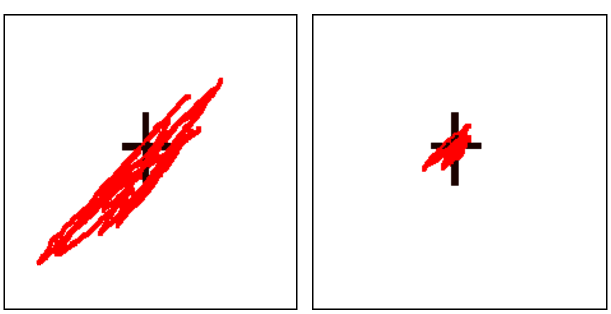

Figure 4. Original and Filtered Tremor trail.

Other measures we intend to incorporate are both empirical and subjective. Empirical measures of pointer coordinates in relation to a central "target" position, measure of velocity and angular regularity of movement will be examined. Subjective measures such as effectiveness of pointer movement smoothing, ability of the pointer to be controlled effectively enough to be useful and not be a distraction, and general ease of use of the software and pointing device while giving a presentation will be explored, as well.

5 Conclusions

There is a definite utility to providing tremor-reduction in software form, as it can apply even as hardware technology and pointing device technology continues rapidly to evolve. A smoother and less jumpy pointer can help eliminate a distraction for an audience during a presentation and provide a presenter who has a tremor of some form with a more comfortable and effective presentation experience. Pointing devices using tremor-reduction software can help those with natural tremors such as Essential Tremor or those with medical conditions that cause other mild to severe tremors. In fact, an approach to tremor filtering may be more widely applicable and useful to a general user, as the tendency to become nervous, and therefore have some mild hand tremor, when making a presentation before an audience is a natural tendency for many speakers.

6 Future Work

The continued refinement of the modified Wiimote Presenter software is of primary interest to us. In addition, some related applications and experiments are on the horizon. A series of experiments is planned to determine the most effective method for tremor-reduction, including the possibility that different forms of tremor will respond better to different tremor filtering algorithms.

Healthcare professionals who treat tremor need more tools to quantify to characterize tremor and therefore measure the effectiveness of various treatments. By extending the functionality of the prototype system, an accurate means of measuring factors such as tremor frequency, amplitude, standard deviation of position in relation to a target, etc., can be developed.

Clearly, a more formula human subjects evaluation is needed, and this will require following rigorous experimental design and approval procedures. Testing the software and a variety of tremor-reduction approaches on subjects with a range of tremor types will provide a means to evaluate which techniques work best for which types of tremor.

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