Haptic Assistance to Improve Computer Access for Motion-Impaired Users

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Abstract

This paper describes a pilot experiment which examines the effectiveness of using force-feedback technology to assist motion-impaired computer users in target selection tasks. Two measures to evaluate the effectiveness of force-feedback assistance are proposed. The radius of curvature of the cursor path and the cursor speed along the path can capture differences in cursor movements that might be lost in a single measure such as time to target. Experimental results indicate that force-feedback implemented as non-directional viscous damping has a beneficial effect for some, improving times to target by up to 50%. Future work includes developing other forms of haptic assistance, developing new measures for evaluation, and investigating the implications of kinaesthesic impairment.

1. Introduction

People with motion impairments have the same desire to use computers as able-bodied people [1], but the typical keyboard and mouse arrangement for computer interaction often presents difficulties. Consequently, there is a need to improve computer access, either by using entirely new modes of input or by augmenting existing ones. Focusing in the latter area, this paper describes a pilot experiment that examines the effectiveness of using haptic feedback to enhance human-computer interaction. In particular, this work investigates the use of a force-feedback pointing device as a means of assisting motion-impaired users in target selection tasks, and extends the work reported in [3].

To determine the effectiveness of various forms of haptic assistance, methods of performance evaluation are required. In other work, measures have been developed for the evaluation of different pointing devices [4]. For the current study, where the pointing device remains constant but the form of haptic assistance changes, these measures can also be applied. One of the most common is movement time. This method of evaluation, however, is based on a single measurement per trial, and although it may be able to establish that a difference exists, determining the cause of the difference is more likely to be accomplished through analysis of cursor movement *throughout* the trial [4]. This paper describes two measures for characterising movement throughout a trial – the cursor velocity along the cursor path and the radius of curvature of the cursor path.

2. Method

A pilot study was performed to investigate the effectiveness of force-feedback technology as a means of assisting motion-impaired users in target selection tasks. Four volunteers were contacted through the Papworth Trust, a charitable organisation dedicated to the care of motion-impaired people. A description of each user is given in Table 1. All participants were familiar with computer and mouse use, as well as with the task to be completed. Force feedback was provided with a Logitech Wingman mouse.

Table 1. Computer users from the Papworth Trust

User	Description
PI3	Athetoid CP, spasm, wheelchair user
PI5	Athetoid CP, deaf, non-speaking, ambulant
PI6	Athetoid CP, ambulant
PI7	Friedrich's Ataxia, tremor, wheelchair user

For the task, participants were presented with 16 "target" circles arranged in a larger circle around a central "home" circle, as shown in Figure 1. The computer users were required to select each target in a random order determined by the software. The circles became red to indicate the active target. Selection was achieved by dwelling inside the target for 250ms. After successfully dwelling on an active target, participants had to select the home circle before the next target was activated.

This task was performed under 4 damping conditions – *None, Acceleration Damping, Velocity Damping,* and *Combined Damping*. In *None*, no force-feedback was applied and the Wingman operated as a normal mouse.

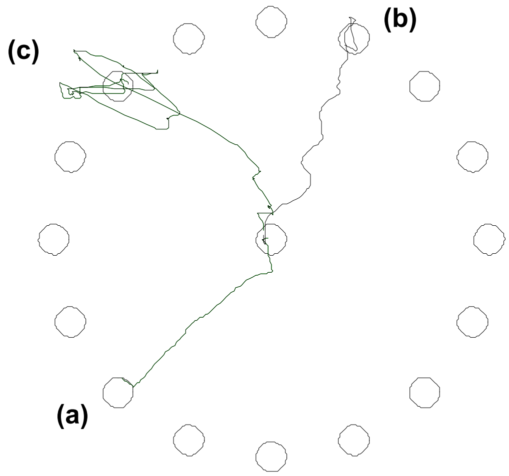

Figure 1. Cursor paths for PI7

Non-directional damping was implemented as a viscous force that increased linearly with mouse acceleration (*Acceleration Damping*), mouse velocity *(Velocity Damping)*, and a combination of the two *(Combined Damping)*. In *Combined Damping*, the velocity damping was at half the strength of the acceleration damping.

Each cursor path was recorded by logging the cursor position and system time each time a mouse message was processed by the operating system. Consequently, cursor position was sampled at irregular time intervals, but at an average rate of approximately 40 samples per second.

3. Performance Measures

In work that has been ongoing in the characterisation of cursor paths, several different measures have been investigated. Here, two of the more intuitive measures – the instantaneous cursor speed along the path and the instantaneous radius of curvature of the path – are described, and their abilities to elicit differences in the cursor paths are illustrated.

3.1. Cursor Speed

Instantaneous cursor speed is approximated as the Euclidean distance between two sample points divided by the time elapsed between them. Cursor speed is a measure that can be particularly sensitive to detecting the occurrence of spasm. During some large spasms, high cursor speeds have been observed, ranging from 3 pixels/ms to 8 pixels/ms. This is in contrast to the speeds observed in controlled movements by able-bodied individuals, typically less than 2 pixels/ms.

Although high cursor speeds cannot always be attributed to spasm with absolute certainty, it is reasonable to relate a high cursor speed with an uncontrolled, and

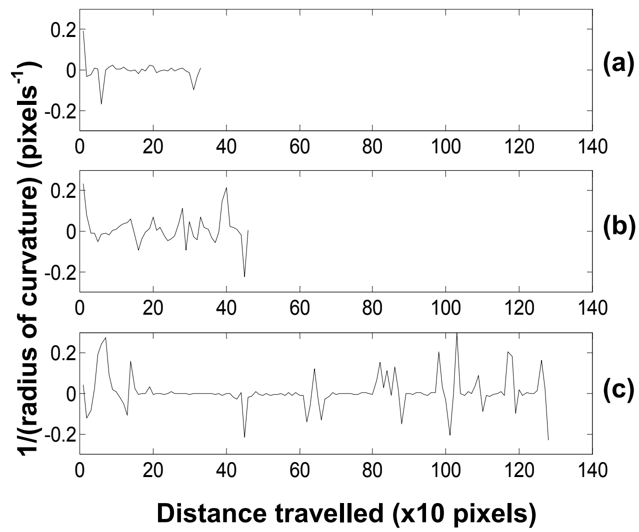

Figure 2. Plots of the reciprocal of radius of curvature for the cursor paths shown in Figure 1

therefore undesirable, movement. Observations of the speeds of able-bodied and motion-impaired users suggest that a threshold of 3 pixels/ms can capture the difference between controlled and uncontrolled movement. The number of times the cursor speed exceeds this threshold can be used to measure the frequency at which uncontrolled movements occur. It will later be demonstrated that damping as a form of haptic assistance can help reduce the frequency of occurrence of high-speed uncontrolled movements.

3.2. Radius of Curvature

A curved path can be represented geometrically as a series of differential arc segments, each formed from the arc of an associated circle having a particular radius of curvature [2]. The radius of curvature, calculated here for an arc length of 10 pixels, can provide information about the number of "twists and turns" in the path. A small radius (e.g. <10 pixels) indicates a sharp turn, and a large one (e.g. >50 pixels) indicates relatively straight motion.

Figure 1 shows the cursor paths for three targets. All three paths have similar time to target values ((a) = 3609ms, (b) = 3974ms, (c) = 4635ms), and so an analysis based on this single measurement would not have revealed any differences among them. A look at the cursor paths, however, shows that the behaviours are quite different. The radius of curvature plots (Figure 2) are able to elicit these differences. The values are plotted as the reciprocal of the radius of curvature, so that high values indicate highly curved movement and low values indicate relatively straight movement.

4. Results

Figure 3 shows the average time to target for the various damping conditions (6 sequences per damping condition per participant, 16 targets per sequence). It appears that all forms of damping have a favourable effect for PI3, reducing times by over 50%. The damping does not appear to have a great effect on times for the other participants. It may be that the nature of their impairments does not benefit so explicitly from the damping, or that the benefit is balanced by the extra motor load produced in moving the mouse. This will be studied further.

Given the reduction in time to target for PI3, the cursor speeds were studied further. Table 2 shows the number of times the cursor speed exceeded the threshold of 3 pixels/ms for the four different conditions. The various forms of damping appear to reduce the frequency of uncontrolled, high-speed movements by 70-90%.

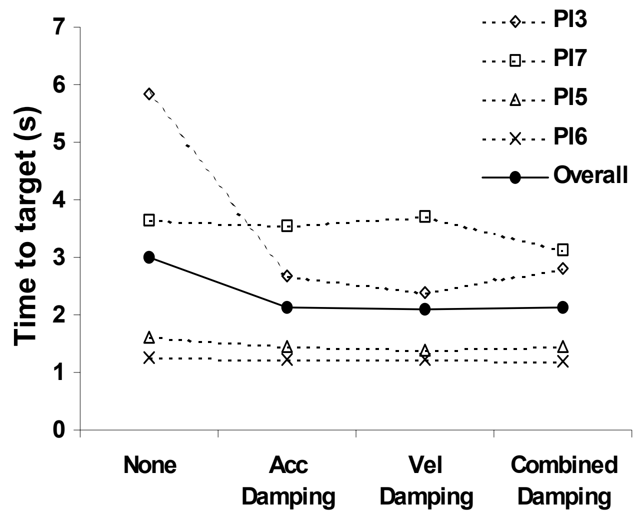

Figure 3. Time to Target vs. Damping Type

Table 2. Thresholding of cursor speed for PI3

Condition	No. of times above 3 pixels/ms
None	70
Acceleration Damping	20
Velocity Damping	6
Combined Damping	14

5. Conclusion

A pilot study has been performed to investigate the effectiveness of force-feedback technology to assist motion-impaired users in target-selection tasks. Two measures for evaluating the effectiveness of haptic assistance have been proposed. The radius of curvature of the cursor path and the cursor speed along the path can capture characteristics of the movement *throughout* a trial which may otherwise be lost in a single measure such as time to target.

In the experiment, haptic assistance was implemented as non-directional viscous damping. The force-feedback appears to be beneficial for some, reducing the time to target by over 50% for one user with spasm. Since force-feedback must be applied appropriately to be of benefit, future work includes developing and evaluating other forms of haptic assistance.

For evaluation, further studies will be conducted to determine the reliability of measures within individuals, across individuals, and across tasks. The measures will be applied to evaluate the effect of various forms of haptic assistance. Further study of the cursor paths will be conducted to gain insight that may lead to the development of more appropriate forms of haptic assistance. Finally, the implications of kinaesthesic impairment on haptic assistance remain to be investigated.

Acknowledgements

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