Evaluating Touch Gestures for Scrolling on Notebook Computers

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Abstract
We describe a new circular touch gesture for scrolling called ChiralMotion™ and report on work to measure its performance. In a study using a document scrolling task, ChiralMotion outperformed linear Virtual Scrolling on a notebook computer TouchPad. Participants also indicated a preference for ChiralMotion in a follow-up questionnaire. We discuss the results and our plans for follow-up studies incorporating other devices.

Keywords
Scrolling, Input Devices, Touch Interfaces, Fitts' Law

ACM Classification Keywords
H5.2. User Interfaces—Input devices and strategies.

Introduction
Measuring scrolling performance across different devices has been an active area of research in recent years, with results reported for mouse wheels, joysticks, scroll rings, and other interaction techniques, using a variety of document scrolling tasks [1, 4, 6, 7, 9, 10].

Our aim with the present work is to introduce a new scrolling technology called ChiralMotion™ and to compare its performance with well-established scrolling techniques. In our initial study we have restricted the domain to vertical document scrolling on notebook computers using TouchPads.

We compared ChiralMotion with Synaptics Virtual Scrolling, characterized by linear strokes in a dedicated "scroll zone" at the right side of a TouchPad. One drawback of Virtual Scrolling is that multiple strokes (or "rowing") are required to scroll long distances.

ChiralMotion for Scrolling

ChiralMotion [2] is a generalized dimensionality-reduction mechanism that allows conventional two-dimensional computer input devices to modally produce one-dimensional input. The technology is particularly suited for use with computer mice and TouchPads and allows all the nuance and expression of the raw device (e.g. pointing) to be retained and exploited in the dimensionality-reduced mode (e.g. scrolling). With ChiralMotion, scrolling is achieved by tracing a circular path with the finger. ChiralMotion eliminates rowing; long-distance scrolling becomes possible with a single continuous motion.

Dimensionality Reduction

A 2D-1D dimensionality reducer accepts two-dimensional data as input and produces one-dimensional data as output. One simple example might be to discard one of the Cartesian inputs as in the case of a class of linear reducers. Another obvious scheme might be to discard one of the polar coordinates as in a class of rotational reducers [6, 7].

The linear reducer, while providing fine-control requires substantial rowing to accomplish longer scrolling movements. Rotational reducers on the other hand, while making progress toward efficient longer excursions, sacrifice finer control [6, 7].

The Chiral dimensionality reduction model intuitively combines linear and rotational motions in a single unified structure. The Chiral model is designed to provide fine control of scrolling and allow unbounded excursions that avoid rowing.

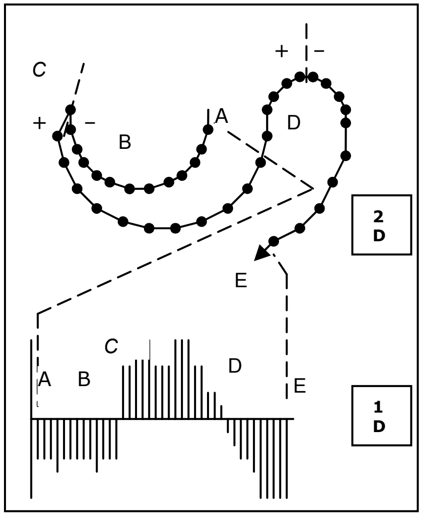


Figure 1. Example Chiral path showing 2D-1D dimensionality reduction.

A precise description of the Chiral model is beyond the scope of this paper; for a complete description see [2]. However the model can be intuitively understood via a few conceptual rules. The initial sign of the 1D variable (i.e., the scrolling direction) is determined by an initial 2D linear movement on the standard "Scroll Zone" of the Touchpad. A linear 2D movement extended by subsequent 2D rotation preserves 1D sign. The 1D sign reverses upon 2D linear or rotational reversal. The 1D magnitude is proportional to the 2D distance traveled.

The application of these rules is visually illustrated in Figure 1. The upper part of the figure shows a 2D movement path and the bottom part shows how the 2D variable is reduced to one dimension, representing scrolling direction and speed. An initial negative 1D sign is established at A by initial downward movement. The 1D sign reverses at C upon a linear reversal at D upon a rotational reversal.

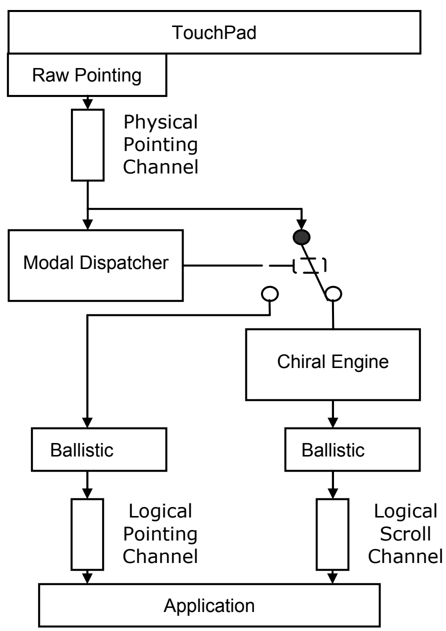


Figure 2. Schematic of TouchPad system with ChiralMotion technology.

Chiral Technology Components

A Chiral-enabled Touchpad consists of three components (Figure 2): a conventional 2D measurement and acquisition subsystem (e.g. Touchpad in 2D mode), a modal selection mechanism and the Chiral dimensionality-reduction engine. The modal selection mechanism in the present experiment is a physical one; to initiate Chiral scrolling on the Touchpad one has to start horizontal or vertical movement on the designated scroll zone of the touchpad (for vertical scrolling, this is at the right edge; for horizontal scrolling this is at the bottom edge).

Scrolling Experiment

We measured performance using a document scrolling task, following the work of Zhai et al. [10] and Buxton and Myers [3] in that we measure time for users to scroll to find a particular line or word and click on it. This is similar to the scrolling experiment used by Hinckley et al. [4], with the difference that our task requires scrolling and pointing rather than scrolling alone. We follow Andersen [1] in keeping the distance to targets unknown. Subjects must search for a highlighted line rather than find a numbered line (as in [4], for example).

Apparatus

The experiment was conducted using two ThinkPad Z61t notebook computers equipped with Synaptics TouchPads. Both computers employed a new version of the Synaptics TouchPad driver software; on one computer the Chiral software engine was enabled, and on the other the default Synaptics Virtual Scrolling was enabled. The driver software was configured with default settings for scrolling speed and all other parameters. The "coasting" feature was turned off for these tests.

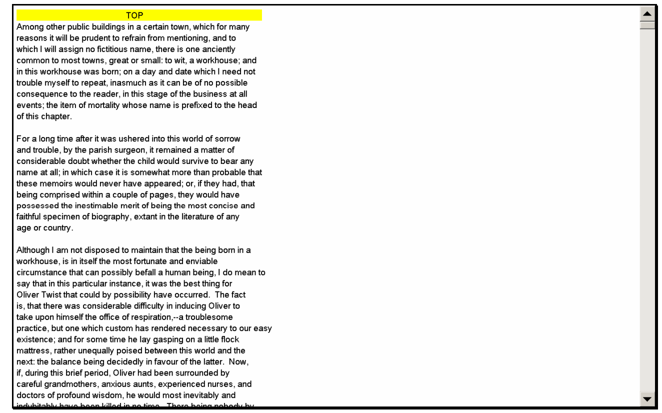
The display resolution on both computers was 1440 x 900 pixels. As described in the following section, the task requires interaction with a text document. The document text was displayed in Arial 14 pt in the Firefox web browser, maximized to a full-screen view with no toolbars. This gave approximately 36 lines on the screen. The Windows XP desktop settings were modified to widen the scrollbar to 35 pixels to make it more prominent. The "smooth scrolling" feature in Firefox was disabled.

Scrolling Task

Figure 3 shows a screen capture of the task at the beginning of a trial. The user is presented with a 2000-line document in a scrollable window. The task is to scroll to find a highlighted target line (indicated in red and bold face) and then click on it by tapping on the TouchPad. Clicking on the target line refreshes the screen to begin the next trial with a new target line.

The initial position within the document and the direction to the target alternated between trials. The first trial started at the top of the document and the task was to scroll down to the target; the second trial started at the bottom of the document and the task was to scroll up to the target. The top and bottom lines of the document were highlighted in yellow.

The task was implemented as a sequence of HTML documents; each is a copy of the same text from a public domain novel and has a different line highlighted, which links to the next document in the sequence. A special "start" page leads to the first page in the sequence, and a "done" page is arrived at from the final page.


TOP

Among other public buildings in a certain town, which for many reasons it will be prudent to refrain from mentioning, and to which I will assign no fictitious name, there is one anciently common to most towns, great or small: to wit, a workhouse; and in this workhouse was born; on a day and date which I need not trouble myself to repeat, inasmuch as it can be of no possible consequence to the reader, in this stage of the business at all events; the item of mortality whose name is prefixed to the head of this chapter.

For a long time after it was ushered into this world of sorrow and trouble, by the parish surgeon, it remained a matter of considerable doubt whether the child would survive to bear any name at all; in which case it is somewhat more than probable that these memoirs would never have appeared; or, if they had, that being comprised within a couple of pages, they would have possessed the inestimable merit of being the most concise and faithful specimen of biography, extant in the literature of any age or country.

Although I am not disposed to maintain that the being born in a workhouse, is in itself the most fortunate and enviable circumstance that can possibly befall a human being, I do mean to say that in this particular instance, it was the best thing for Oliver Twist that could by possibility have occurred. The fact is, that there was considerable difficulty in inducing Oliver to take upon himself the office of respiration,--a troublesome practice, but one which custom has rendered necessary to our easy existence; and for some time he lay gasping on a little flock mattress, rather unequally poised between this world and the next: the balance being decidedly in favour of the latter. Now, if, during this brief period, Oliver had been surrounded by careful grandmothers, anxious aunts, experienced nurses, and doctors of profound wisdom, he would most inevitably and

Figure 3. Experiment screen at beginning of trial, showing highlighted top line.

Participants

Eight Synaptics employees (7 male, 1 female) volunteered for the study. All had prior experience using linear Virtual Scrolling on TouchPads and had also used Chiral scrolling in prototype software.

Variables and Design

The dependent variable in the experiment was task completion time in seconds, as recorded by event logging software. A trial began when a new page was displayed on the screen, and ended when the user tapped to select the correct target line.

The independent variables in the experiment were device (linear or ChiralMotion) and distance to target line. Distance varied over the range of 200 through 1800 lines in increments of 200, giving 9 distances. A random ordering of these 9 distances was chosen and this ordering was presented for each block of trials. A different ordering of 5 distances was used as a practice block. Each participant performed two repetitions of the practice block (2 × 5 distances) and two repetitions of the main block (2 × 9 distances). Each participant performed all blocks with both devices, half using linear scrolling first and half using Chiral scrolling first.

Post-Test Questionnaire
In addition to the quantitative test, participants answered a questionnaire that asked for ratings along several scales including ease-of-use, fatigue, accuracy, speed, smoothness, and likeliness to use the scrolling technique regularly if it were available to them.

Results

Task Completion Time
Figure 4 shows average time for all participants plotted against target distance. Practice trials are excluded from this data. Across all distances the average movement time using Chiral scrolling was 11.0 seconds (standard deviation 4.4 s) and using linear scrolling it was 17.4 s (standard deviation 10.0 s). An analysis of variance revealed a significant difference between the two devices ($F = 76.5$, $p < .05$).

We tested two linear regression models: time vs. distance and time vs. Fitts' Index of Difficulty (ID), on data pooled according to standard practice with Fitts' Law studies [4, 5, 8].

The time vs. distance regression gave $R^2 = 0.97$ for Chiral and $R^2 = 0.77$ for linear scrolling. The strong fit of this model favors the conclusion of Andersen [1] that this model is appropriate for scrolling tasks where the distance to the target is unknown.

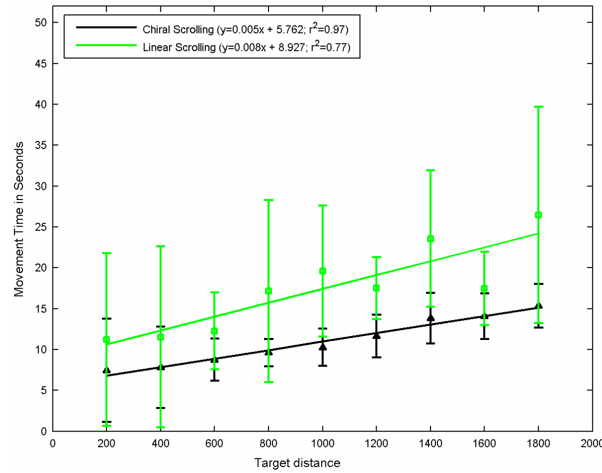


Figure 4. Average task completion time by distance.

For the Fitts' Law model we computed ID as $\log_2(\mathit{Distance}/\mathit{Width} + 1)$ with $W = 1$ line. The quality of fit here is somewhat weaker ($R^2 = 0.82$ for Chiral, $R^2 = 0.70$ for linear), suggesting that index of difficulty as computed here is not appropriate for this task. Our task did not consist simply of an aimed movement to a target; rather the task was to scroll to make the target appear on screen and then move the cursor to select the line.

Questionnaire Responses
All participants rated Chiral scrolling superior to linear scrolling, both in a general preference question and on the rating scales shown in Figure 5.

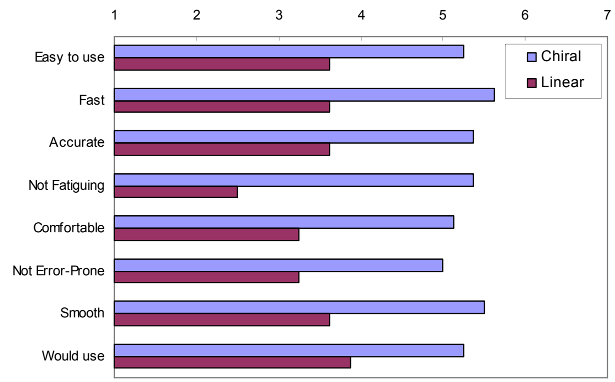


Figure 5. Average device ratings. A value of 7 corresponds to "Strongly Agree" and 1 corresponds to "Strongly Disagree".

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Discussion and Future Work

In our experiment, ChiralMotion™ technology for scrolling outperformed the established technique of linear scrolling on notebook computer TouchPads. We plan to extend this work with an improved experiment that more closely follows prior test frameworks for scrolling and that tests additional technologies, including two-finger TrackPad scrolling on Apple MacBook® computers and physical scroll rings [9]. We also plan to test with a larger set of users and measure learning times for users with no prior exposure to the technology.

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