# Rock 'n' Scroll Is Here to Stay

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**The Rock 'n' Scroll input method lets users gesture to scroll, select, and command an application without resorting to buttons, touchscreens, spoken commands, or other input methods.**

Not missing a chance to show off the latest pictures of your children, you reach for your new photo album. As you remove it from your pocket, it activates and you see a display of photograph thumbnails in the album. Tilting the album on either axis scrolls through the thumbnails until you find the pictures you want to show. A gentle fanning gesture zooms in on the first picture, then you hand the album to your friend. After admiring the picture, she gestures to step through the rest of the album. The pictures are in both landscape and portrait mode, so a simple gesture is all that's required to reorient the album to best display them.

Before putting it back in your pocket (where it will automatically shut down), you stop to admire the album itself. The album's dimensions are that of the display with the addition of a thin, black border. In keeping with its spare, elegant design, it has no buttons or other visible controls: all functions can be accessed by direct manipulation.

While such an appliance has yet to reach the market, my colleagues and I have constructed a prototype that demonstrates the user interface we call Rock 'n' Scroll.

The photo album is an example of a device with an Embodied User Interface,[1] where the control mechanism is directly integrated into the album's display. The design of such a device draws on a long-standing interest in using motion sensing for user input and the realization that inertial sensing systems are the logical type of system to embed in small devices.[2] While researchers have anticipated tilting a personal digital assistant (PDA) to navigate through a document, only in the last two to three years have the sensors become small, cheap, and sufficiently low power that they can be embedded in a handheld device and realize this vision.

## Tilt to scroll

For desktop devices, scrollbars have become the de facto control mechanism for paging through documents larger than the screen. When user interface designers use scrollbars on the smaller display of a handheld device, two problems arise: both horizontal and vertical scrollbars are often required, and the scrollbars occupy a larger percentage of the screen. Designers can recover the display area used by scrollbars by allowing scrolling by dragging the document using a stylus or scrolling via a cursor key. However, all these techniques still require the use of both hands. One way to free a hand is to use the hand that holds the device to control scrolling. As users rotate the device in their hand about either or both axes away from a user-defined neutral orientation, the device senses the motion and the screen contents scroll appropriately, as shown in Figure 1.

As described, scrolling is always on, just like dexterity puzzles that you tilt to get the rolling ball in the correct hole. This isn't always the desired behavior, so other systems that have investigated "tilt to scroll" have provided a "clutch" button to engage scrolling.[3-6] When pressed, the device's tilt scrolls the display; otherwise, scrolling is disabled.

The clutch button seems a good solution to accidental scrolling, but it comes at some cost. In some simple user tests that we conducted at the start of this investigation, users complained about having to tilt the device and press the button in a synchronized manner. For tasks like reading a column of text, users often want to continuously scroll and don't want to keep their hand tensed to hold the button down the whole time.

Finally, any time you provide a button, you make an assumption about how the user will hold the device and push the button. One solution to this problem is to add more buttons. A more elegant one is to make the whole device a button, where the user squeezes it to enable scrolling.[4] Or, you can make the scrolling behavior modal.

Rock 'n' Scroll uses the last approach. We assume scrolling is the device's normal mode and provide com-

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**1** As the left edge of the device is dipped, that is, rotated about the roll axis, the picture slides to the left of the display.

**2** The first frame of the sequence (left-to-right, top-to-bottom) shows the thumbnail photo. In the next three frames, the user fans the device. The fifth frame displays the full-size picture.

mands to disable and enable scrolling and to set the device's neutral orientation. However, for this behavior to be an improvement over a "clutch" button, the application designer must ensure that frequent mode switches aren't required.

## Gesture to control

The commands that control scrolling can be issued in any number of ways, including button presses or interaction with a touchscreen. The same inertial sensors that control scrolling can also be used to recognize gestures as commands—this is the method we chose for Rock 'n' Scroll. Levin and Yarin[7] have also investigated this method to implement a tilt- and shake-sensitive interface for drawing.

Other possible command gestures include snapping or shaking the device, tapping on it with the other hand, or fanning it. Unlike Levin and Yarin's implementation,[7] we rejected snapping and shaking the device because of the strain it places on the user's hand and wrist. The mass of a 4- to 6-ounce device proves sufficient to strain users when they repeatedly perform such a gesture. Tapping is attractive because it doesn't require users to move the device, but it does have the disadvantage of requiring a second hand to operate.

We then tried slower fanning gestures about either of the device axes. The gentler motion seems easier on the hand and wrist than a snap, and the longer duration of the gesture makes it easier to separate it from high-frequency noise like hand tremors and vehicle vibrations. The sequence of pictures in Figure 2 illustrates how to select a picture from the album with a downward fanning gesture about the roll axis. The first frame shows the thumbnail picture. Then the user smoothly dips and raises the left-hand edge of the device to display the desired picture.

Three other similar gestures—upward about the roll axis, downward about the pitch axis, and upward about the pitch axis—can also be made. When combined with scrolling, they provide a vocabulary of commands more than sufficient to implement the rest of the album's commands: step from a picture back to the menu of thumbnails, step to the next picture, disable and re-enable scrolling, and reverse scrolling direction.

The gestures don't require a large amount of space to execute. For example, they can be performed with a user seated with an elbow on a chair's armrest. When users hold the device as shown in Figure 2, the device motion is in front of them, and those seated on either side aren't disturbed.

## Hold still to orient

The final gesture used in the photo album is holding the device still for a couple of seconds, which serves two

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purposes. The first is that it reorients the device. In Figure 3, the user moves the album from landscape to portrait mode by positioning it vertically with the new top edge of the album up. The user holds the album still in that position for a couple of seconds, then the screen image rotates to the new orientation.

The second purpose of the hold-still gesture is to change the album's neutral orientation. To do this, the user first gestures to disable scrolling, then holds the device still in the new neutral orientation for a couple of seconds, and gestures to enable scrolling. While this operation takes three gestures to accomplish, it's not a burden to users because they perform the task infrequently.

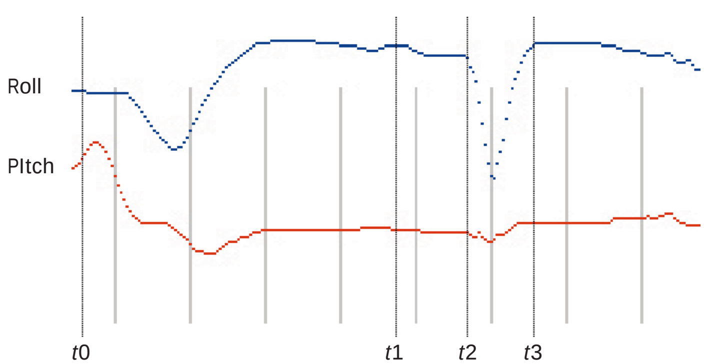

**3** **As shown in the sequence, the user positions the album in the desired orientation, then holds it for a couple of seconds to change the display from landscape to portrait mode.**

## Implementation

Now that I've demonstrated the mechanics of controlling the device, we can turn our attention towards its implementation. Verplaetse[2] characterized the motion that should be expected as accelerations from 0.1 *g* to 1.0 *g* and a frequency of motion of 8 to 12 Hz. The inertial detectors must also meet the needs of a personal device: rugged, self-contained, small, light, and low power. Finally, we need low-cost detectors to meet the manufacturing cost requirements for mass-market digital appliances.

With these design constraints in mind we chose a two-axis, single-chip accelerometer—Analog Devices' ADXL202—to measure acceleration on each of the device's axes (see Figure 1). With the addition of one resistor and three capacitors, we integrated it into Itsy,[8] Compaq Research's experimental platform for "off the desktop" computing. Every 10 ms, the ADXL202 reports acceleration values in the range of –2 *g* to +2 *g* for each axis. These measurements are averaged in groups of four, so the photo album application sees 25 sets of measurements per second. These values represent a combination of gravitational acceleration, user motion, and noise. Initial noise filtering occurs by using a low-pass filter in the accelerometer set at 10 Hz. Exponentially averaging sequential results achieves additional filtering. When plotted over time, the values look something like Figure 4. At time *t*0 the user is scrolling the display by rocking it fore and aft. By time *t*1, the user is holding the device fairly still. At time *t*2, a gesture like that shown in Figure 2 starts and is completed at time *t*3.

Figure 4 illustrates a problem with extracting both gesture and scrolling information from the same data stream. The user thinks the gesture starts at time *t*2, but the device doesn't recognize it until *t*3. During this interval, scrolling continues on both axes, so the application may scroll from one item to the next in a menu and the gesture's action is applied to the wrong object. This can be seen in Figure 2, where in the fourth frame, the thumbnail menu is scrolling because the gesture has not yet been recognized. To correctly associate the gesture with the right device state, the scrolling code is speculatively executed by saving the time and current scrolling state before each change occurs. When the system recognizes a gesture at




**4** **Acceleration versus time for each axis of motion is plotted here. Each signal is labeled and shown independently, with the acceleration value on the vertical axis and time on the horizontal axis. The vertical gray bars are at one-second intervals, and dotted vertical lines denote points of interest.**

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*t*3, the system restores itself to the state at *t*2 (shown in the first frame of Figure 2), then applies the gesture's operation. The scrolling state need not be saved indefinitely, since a maximum length of a gesture can be defined.

### But will it work?

Before implementing Rock 'n' Scroll for Itsy, we constructed a prototype system to test the ideas. The prototype system appears to the user as a handheld computer with a cable leading out of it. It consists of a small video liquid crystal display (LCD) with a two-axis accelerometer attached to the back. The accelerometer was made from two earlier generation (Analog Devices ADXL05) one-axis accelerometers and included a PIC16C73A microcontroller to convert the analog outputs from the ADXL05s into digital values reported 25 times a second to a PC via an RS-232 serial line. The measurements drive a PC application whose output to the screen is converted to a National Television System Committee (NTSC) video signal via a scan converter, then displayed on the LCD. The prototype is decidedly inferior in handling to an Itsy, since it is larger and heavier, its screen has a narrower viewing angle, and it is tethered to a PC.


**5 In the frame on the top, the picture is in the initial position. When the left edge of the device is dipped, seven of the fifteen subjects expected gravity to "slosh" the picture into the position it has in the center frame, and five of the fifteen subjects expected to see the picture like the bottom frame because they "pointed" with the left edge of the device to that corner of the picture.**

Applications constructed include a viewer allowing users to scroll through a number of pictures and text images, a game where a cat catches mice, and an interactive map of our building. The map application lets users tilt to browse a floor and gesture to change floors, set the device's neutral orientation, or disable or enable scrolling. Fifteen members of Compaq's Palo Alto research labs participated in a scripted trial that took about twenty minutes per person. During the trial the user stood and manipulated the test system under my instruction.

The most important goal of the study was to confirm (or reject) the premise that the Rock 'n' Scroll user interface can be rapidly mastered by a larger user community. Test users first familiarized themselves with the device by scrolling text and pictures. With little practice, they were able to start and stop scrolling, find specific articles in the text, and center selected items in a picture on the screen. Next, we demonstrated the map application, then the users tried it. A subjective measure of their ability to operate the application was then made based on the three to five minutes that they used the application. Three quarters of the users found it easy to operate all features of the application. One quarter of the users had moderate difficulty making one or more of the types of gestures. With some coaching and adjusting of the gesture recognizer, all users were able to make all types of gestures.

The more interesting result though, has to do with user expectations about how the device would scroll. As the prototype hardware and software were being constructed, we observed that users have different (and often strong expectations) about which way the display should scroll when they tilted the device. For example, when the left edge of the device is dipped, should the picture on the device slide left or right? We designed the user study to examine this and found that while a default sensitivity and scrolling speed was acceptable, a default scrolling direction was not. For each user, the initial scrolling behavior was randomly selected. As the tests were run, the users were allowed to change scrolling behavior to a preferred setting, while the experimenter encouraged them to try the alternative as well. All but two test subjects immediately chose a preferred direction and maintained it across the entire test. The results, summarized in Figure 5, suggest that the world is divided into "sloshers" and "pointers" who expect the device to behave in opposite ways.

However, when presented with a simple game, all subjects but one expressed a strong preference for the "slosh"

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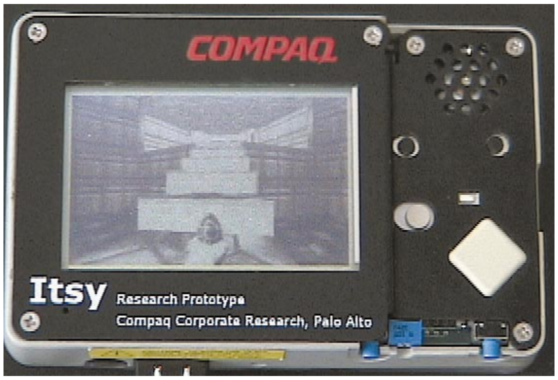
**6 Cat and mouse game.**




**7 Doom on Itsy.**


**8 Industrial glove with hands-free thermometer (mock-up).**

mode of operation. The game, shown in Figure 6, displayed a cat on the screen. The user tilted the device to move the cat around to catch mice. Those who favored the "slosh" mode of operation in the earlier parts of the test explained that when they dipped the left edge of the device, they expected the cat to go left. Those who "point" explained that they were pointing to where they wanted the cat to go. Though the test subjects had different explanations, the end result was that they expected the device to behave in the same manner.

We also observed this behavior with the game Doom that we ported to Itsy. In Figure 7, virtually all users expected that when they tilted the top edge of the display down, they'd move up the stairs. Whether they sloshed the gun up the stairs or pointed to where they wanted the gun to go, the action and expected result were identical.

Directly manipulating a handheld computer to play games fascinated nearly all subjects. The simple cat and mouse game on the prototype was surprisingly compelling, and users would often continue to play with it for a few minutes after their test session ended. When watching users play Doom on an Itsy, it's clear that they had significantly more kinesthetic satisfaction in tilting the device than in rocking a cursor key.

## A limit to embodied user interfaces

An alternative way to play Doom is to maneuver using the diamond-shaped cursor key to the right of the screen. This offered an opportunity to determine user input preferences for this application. We encouraged users to play the game using both input methods and polled them later about their preference. The seven respondents to the poll were evenly split in their preferences: three preferred the cursor key and four preferred tilt-to-scroll. However, when their user interface preference was correlated with their level of experience playing electronic games, all those with extensive experience preferred to use the cursor key and the rest preferred tilt-to-scroll. Experienced users felt they could maneuver with more precision with the cursor key and didn't like the fact that an enthusiastic press of the fire button would move the player. Less experienced users preferred to tilt-to-scroll and described that method as more natural or intuitive than the cursor key.

While most users had positive things to say about the Rock 'n' Scroll interface, they also noted some problems with the display while playing the game. The Itsy display is a reflective LCD, so ambient light conditions can cause significant changes in screen visibility as the device tilts. In addition, enthusiastic play often results in significant tilt that exceeds the viewing angle of the display. While LCD technology will improve and reduce these effects, some experienced users observed one display difficulty inherent in embodied user interfaces: perceived motion on the screen is the sum of the motion of the embodied device and the changes made to the display by the device. As you interact with the device by moving it, the orientation of the display to the user changes, then in response to that motion the display contents move on the display. For "twitch" games like Doom, where the user manipulates the device rapidly, tilt-to-scroll results in motion on the screen that may be harder to visually track than motion via the cursor key. On the other hand, for applications like the photo album, where the user is not rapidly manipulating the device while trying to track moving fine detail on the screen, this should not be an issue. The results from this small test suggest an area for further study.

## Additional ways to Rock 'n' Scroll

In the discussion to this point, users always held the device in either or both hands. However, since all interaction occurs by manipulating the device, it could also

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