New Touch Screens Improve Handheld Human Interface

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The touch screen is a vital component of the human interface in handheld, wireless devices. As the handheld human interface becomes richer and more complex, the demands on touch screen technology will only increase. Fortunately, new technological developments in touch screens are addressing the demands of the modern handheld human interface.

In the past, handhelds were neatly categorized into phones, pagers, personal digital assistants (PDAs), and so on. Each category was simple and well-defined and called for a simple input device: Phones had keypads, pagers had a few buttons, and PDAs had touch screens for handwriting and selection. Today, all these products are growing more complex: Phones have intricate menu systems, pagers offer messaging input, and PDAs are evolving into full-fledged computers with Internet connectivity. Meanwhile, the categories are converging. For example, a device incorporating both phone and PDA functions may not have space for both a keypad and a touch screen, so ways must be found to use the touch screen for basic dialing with the ease and familiarity of a keypad. Simplicity and convenience, as well as functionality, in the human interface will become powerful product differentiators. Thus, the evolution and convergence of handheld devices is driving advances in the human interface, and many of these advances hinge upon the touch screen.

New alternatives in touch screens

Most handheld touch screens today use resistive technology. In a resistive touch sensor, a conductive membrane is suspended over a conductive substrate (Figure 1). The conductors are electrically resistive sheets with taps on the edges or corners. Pressure from a pen or finger bends the membrane into contact with the substrate to form an electrical circuit. The controller locates the pen or finger by measuring the resistance between the point of contact and the edges or corners. In a touch screen, the membrane and substrate are made of clear materials (glass and/or polyethylene terephthalate, PET, a clear plastic film) coated with a thin layer of semi-transparent metal, indium tin oxide (ITO). Because it is difficult to suspend the membrane above the substrate by mechanical tension alone, the air gap in between is often filled with tiny spacer dots.
Resistive touch technology is familiar and mature, but it suffers many drawbacks. Resistive sensors are mechanically complex and hard to build on non-rectangular, curved, or very thin surfaces. Performance with fingers is poor due to the need for physical pressure; it is difficult to tune the sensor to work well with both fingers and pens. Resistive sensors cannot distinguish pens from fingers, nor can they detect proximity of a pen or finger without actual pressure. The top membrane is a moving part, vulnerable to mechanical damage and wear. As the resistive sheets wear, performance degrades and the sensor requires periodic recalibration.

Finally, in touch screen applications, resistive sensors seriously degrade image quality. Their ITO layers reduce the transmissivity to light and discolor the light from color or paper-white displays. Their multiple air-glass and air-plastic interfaces cause stray reflections. Normally this could be overcome with anti-reflective (AR) coatings, but resistive sensors have flexible surfaces incompatible with AR coatings. The gap between the layers can be filled with a refractive-index-matched liquid to eliminate stray reflections, but this adds further cost and complexity.

All these factors encourage the investigation of new touch screen technologies such as capacitive and inductive sensors. Capacitive touch screens use a thin layer of ITO to sense the proximity of a finger by capacitive coupling (Figure 2); they work extremely well for fingers but do not sense pens. Inductive touch screens sense a pen containing a special resonant coil; other coils within the touch screen excite the resonant coil and detect the resulting ringing by magnetic proximity sensing (Figure 3). Both technologies have suffered until recently from costly, power-hungry control electronics and strong edge effects, effectively limiting them to large-form-factor applications such as kiosks, gaming machines, and writing tablets.
New capacitive and inductive technologies, such as the ClearPad™ and Spiral™ sensors of Synaptics, are addressing the special needs of the wireless handheld market. These technologies meet all the basic needs of handhelds, with integrated, low-cost, low-power controllers and sensors that are specially designed for small screens and tight spaces. Capacitive and inductive sensors also offer other advantages that contribute to the handheld human interface.

To sense pressure from the pen, a resistive sensor must be mounted above the LCD. The poor optical characteristics of the resistive sensor significantly impair the brightness, contrast, and overall visual quality of the display. Inductive
sensors, on the other hand, operate by magnetic sensing and are not affected by LCD materials. Hence, an inductive sensor can be mounted *behind* the LCD. By not obstructing the LCD, the inductive sensor yields a much brighter, clearer, better looking display. Because the surface does not need to be flexible, AR coatings may be used to further improve display quality. The result is a night-and-day difference in usability of the display.

Most handheld displays include a backlight or frontlight to overcome the image degradation due to the touch screen. With inductive sensing, the backlight can be turned down or even eliminated to attain the same quality of user experience. In one study, a Compaq iPaq was modified to replace its resistive screen and frontlight with a Spiral inductive sensor. With this modification, the display contrast improved from 39% to 91% and the brightness increased by 58% in typical outdoor conditions. In indoor conditions, the display was readable with no frontlight; because the frontlight accounts for a large fraction of the power budget of the system, this change more than doubled the expected battery life from 115 to 260 minutes. Eliminating the resistive sensor and frontlight also reduced the potential thickness of the iPaq unit by 2.2 mm and the weight by 27 g.

Most handheld products with resistive screens need some kind of removable cover to keep the sensor’s delicate membrane safe from harm. This cover significantly complicates the industrial design and interferes with desirable usability features. For example, the Palm II, III, V, and m100 handhelds have tried very different protective cover designs. In all but the last of these designs, the cover completely obscured the display when closed. By contrast, many cellular phones feature displays that are exposed to view at all times. As well as greatly simplifying the design, the exposed LCD allows the product to display useful information when it is idle. This information, such as battery life, signal strength, and messaging status, adds significant value to the product in the form of convenience and usability.

Inductive and capacitive sensors, being proximity sensors, can be mounted behind tough outer coatings like hardened glass or scratch-resistant plastic and made as rugged as any LCD. Thus, the product designer is no longer forced to choose between the convenience of an exposed display and the advanced user interface made possible by a touch screen. In one experiment, a RIM 957 pager with an exposed, non-touch-sensitive LCD was modified to include a ClearPad capacitive touch sensor. The resulting unit exhibited excellent finger touch performance with no observed loss of durability.

**Improving the user interface**

Handheld devices have evolved from simple information managers to sophisticated personal computers. Where simple selection and handwriting entry sufficed for earlier systems, modern handhelds require richer, more powerful user interfaces. Indeed, some handheld operating systems (notably Microsoft
Pocket PC) strive to give the user a computer-like experience in a handheld form factor. The touch screen of a handheld computer substitutes for the mouse of a conventional computer. Where the user of a conventional computer would move and click a mouse to select an icon, the handheld user simply taps directly on the icon with the pen. The mapping from pen to mouse seems natural, but on closer inspection, there are differences that have a significant impact on the user interface. One example is the ability to offer pop-up help.

With a mouse, pointing and selecting are two separate actions. The cursor is moved over an icon, then a button is clicked. Modern software applications use this fact to provide useful cues to the user in the form of pop-up help. If the user moves the cursor over the icon and holds it without clicking, the application displays a small transient box with text explaining the purpose or effect of the icon. Pop-up help allows applications to use more numerous, smaller, or more abstract icons without cluttering the screen with explanatory text. In many applications, pop-up help has evolved into a rich assortment of useful pop-up information.

Consider the analogous situation on a handheld computer. The user holds the pen over an icon without pressing down. With a conventional resistive touch screen, the machine cannot sense the pen until pressure is applied. Hence, the system is unable to offer pop-up help; the icon is not identified in any way until the user has already selected it. Ironically, it is precisely in a handheld device (such as a PDA or cell phone) that pop-up help is most needed because screen space is at a premium.

Because inductive and capacitive touch screens can sense the proximity of the pen or finger, they support pop-up help in an easy and natural way. The Spiral inductive pen includes a pressure-sensitive tip that allows it to distinguish cleanly between resting on the surface and being pressed or clicked. Spiral-enabled applications and operating systems can display pop-up help whenever the user hovers on an icon without clicking. Adding pop-up help to the handheld repertoire not only greatly enhances the user interface, it also eases cross-portability of applications between handheld and desktop systems.

User interfaces tend to involve two distinct types of activities. Some, like text selection and handwriting, are spatially precise and highly intentional; others, like menu operation, tend to be spatially coarse and more spontaneous. User interfaces often provide separate mechanisms to distinguish these types of actions. For example, the Palm OS has a separate area for handwriting entry; the Windows desktop OS uses the left mouse button for selection and the right button for commands. A natural way to implement this distinction in handhelds is to assign the pen to precision pointing and handwriting, and the finger to command entry. Unfortunately, a resistive touch screen is unable to distinguish pens from fingers.
Capacitive and inductive sensors do not inherently interfere, and indeed it is possible to create a hybrid sensor that not only senses both fingers and pens better than a resistive sensor, but also clearly distinguishes the two types of input. Capacitive/inductive hybrid touch screens show much promise in the area of enriching the handheld human interface.

Another intriguing possibility in the handheld interface is finger-driven handwriting. Many handheld devices, such as PDAs, now accept handwriting input. Traditionally a pen or stylus is used for handwriting. Studies at Synaptics and its partners have shown the surprising result that fingers are equally good writing instruments when the input device is well-adapted to fingers. Capacitive touch sensors work exceedingly well with fingers. In one study, a cellular phone keypad was replaced by a capacitive touchpad equipped with handwritten digit recognition software. User tests showed that this phone was remarkably easy to dial. In addition, the handwriting paradigm was easy to extend with letters or other symbols, whereas phone keypads cannot accept many additional buttons without confusing the user. Also, dialing by handwriting is easy to do without looking at the device; this suggests that a phone with a ClearPad capacitive touch screen in place of a keypad might actually enhance driving safety as well as solving a tricky design problem as phones get ever more compact.

The human interface of handheld devices is still a subject of much research and innovation. Because the touch screen is so integral a component to the human interface, advances in touch screen technology will enable handhelds to combine functionality, usability, and convenience to a degree never before possible.