Hidden interfaces: a new playground for embedded innovations

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The rate of innovation is stagnating, say some analysts (**Reference 1**). The complaint is that the highly visible, and hyped, innovations fall into an incremental and predictable pattern that focuses on cost savings. Areas identified for innovation in 2012 include social media, information flow, and application stores. Another area for innovation is camera-based interfaces, such as Microsoft's Kinect, which promises users a richer way to interface with their consoles and computing devices, but the hardware's $249 price puts this technology beyond the range of most embedded applications. Despite these roadblocks, a number of hidden interfaces are quietly finding their way into more systems; many of these interfaces can detect a user's presence and motion. A hidden interface is one in which the system provides no prompt for the user. Thus, proximity sensing, which involves detecting that a user is within range of a sensor, is a hidden interface because, in most cases, the user knows neither that the system is performing such sensing nor why it is doing so. Motion sensing is a potential hidden interface because the motion sensing occurs, despite the presence of the user, to allow the system to adjust and adapt its behavior based on where and how it is being handled.

Proximity-sensing interfaces rely on a variety of technologies. For example, automobiles that support keyless entry detect when a user is approaching the vehicle and unlock the door before the user can pull the door handle to its full open position. Additionally, on some vehicles, these systems, along with an ambient-light sensor to detect dark conditions, may turn on lights outside the vehicle to make it easier for the user to find the door handle. In addition to detecting the presence of the user, proximity sensing enables designs to explore ways to offer touchless and motion-sensing interfaces to complement pervasive touch technologies.

Motion-sensing innovations are showing up in game consoles, such as the Nintendo 3DS, and mobile devices, such as smartphones and tablets, as they take increasing advantage of built-in gyroscopes to provide new ways to pan the display. The gyroscope-based panning capability allows a user to see the contents of the display change depending on where and how he is holding the viewing device. For example, the technology allows users to explore a famous panoramic tourist site from a 360° perspective by spinning around to see what is behind them. This hidden interface allows the presentation of the content to integrate with more of the user's own inertial sensing, which can provide better feedback than dragging a finger across the display to pan an image.

These emerging, hidden interfaces are becoming more practical for designers to include in designs because the cost to include them continues to drop—in many cases, to as low as approximately a few dollars or less. The companies providing such sensing products also provide software libraries and engineering support so that embedded-system developers need neither become experts on the proper integration of these products nor work with the analog and digital components.

Available sensing approaches for proximity and motion detection include capacitive proximity detection, infrared- and ambient-light sensors, and dual-core gyroscopes.

Capacitive proximity

Capacitive sensing started to take off with the ubiquitous adoption of touchscreen interfaces in smartphones and tablets, such as the iPhone. As the sensing technology continues to mature and the production costs drop, capacitive sensing not only supports explicit touch and gestures but also, through proximity sensing, provides systems with more information about how the user is using the system. A key hidden-interface feature is the ability to detect and reject unintended touches, such as when a user's cheek touches the interface when he places the phone to his ear or when a user grips a device, thereby touching its edges.

Figure 1 The Cypress Semiconductor CY3235 proximity-detection demonstration kit shows how to use the PSoC (programmable-system-on-chip) CapSense-enabled CY8C21434 to accurately sense the proximity of a hand or a finger along the length of a wire antenna.

Recently announced capacitive-sensing products, such as the Atmel QTouch AT42QT2120 and the Cypress CY8C21434, have increased the range of proximity sensing to support distances as long as 25 cm (1 foot). The companies supporting capacitive proximity sensing provide engineering support, application notes, and demonstration kits to help designers (**Figure 1**). The ability to reliably support capacitive proximity sensing at longer distances involves the use of algorithms that have been maturing over the past few years. These algorithms can now adjust the sensitivity gain of the sensor depending on whether it needs to perform proximity or touch sensing.

Proximity sensing enables designers to keep energy-hungry portions of the system in a deeper sleep state and wake them up just before a user makes contact. This approach can provide a better user experience because the system can react as if it were in an always-on condition without always being fully on. This type of sensing is useful for applications such as waking a wireless mouse and turning 3-D glasses on and off for television systems.

Capacitive proximity sensing requires the use of few or no extra components if your system also supports a capacitive-touch interface. The technology suffers, however, from the same weaknesses as capacitive touch: It works well with a user's bare fingers but less well with a user's gloved fingers when, for example, the user is employing the device outside on a cold winter day. This problem creates the opportunity to provide new or more reliable capabilities that rely on sensor fusion—that is, combining inputs from multiple sensing technologies. For this example, infrared proximity sensing nicely fits the bill.

Infrared proximity

Infrared- and ambient-light sensors can provide complementary sensing, including capacitive-touch sensing, to enable sensors to further adapt their operation to environmental and contextual conditions. Infrared proximity sensors commonly find use in automatic doors; lavatory toilets, soap dispensers, and paper-towel-dispensing systems; and mobile touchscreen devices. A mobile system with a display can improve the system's battery life by detecting whether the presence or lack of light affects the viewing conditions of the display and can automatically adjust the brightness to improve readability without any action on the user's part.

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The Kindle Fire and Nook Touch demonstrate another advantage of infrared sensing over capacitive-touch sensing. Both systems use an infrared touch system because it requires no indium-ti--oxide layer over the display. This approach enables a single-layer capacitive-touch sensor to have as much as 90% transparency, improving readability and providing a noticeable quality similarity between E Ink-display output and the printed material.

Infrared proximity sensing supports the new hidden-interface capabilities employing an active-sensing approach. In a passive-sensing approach, the sensor identifies changes in the ambient-light input. For example, when a person approaches an automatic door, the sensor causes a change in detected light. However, if the person then stops, the passive sensing may eventually establish a new baseline so that the system does not recognize that the person is still standing in front of the door. An active-sensing approach, in contrast, uses one or more infrared-light-emitting diodes to find reflections of known pulses of infrared light. Infrared sensing can complement capacitive-touch sensing by enabling a system to know when it should reject touches. It can also save system energy by shutting down the display when a user places a smartphone on his ear and turning the display on when the user pulls the smartphone away from his face.

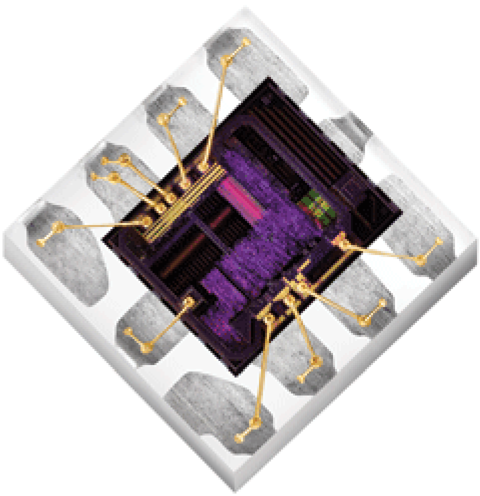

Figure 2 Silicon Laboratories' Si114x QuickSense infrared sensors pack as many as three independent LED drivers into a 2×2-mm QFN-10 package and support a sensing range as long as 50 cm, virtual slider buttons, and three-axis motion and gesture sensing.

The latest generation of small, low-power infrared sensors, including Silicon Labs' Si114x family of sensors (**Figure 2**), may also be able to drive multiple infrared LEDs to enable detection-gesture inputs in multiple dimensions. The cost to include infrared sensing currently ranges from approximately 60 cents to around $1 in volume, depending on the number of infrared LEDs and corresponding sensor required.

Some next-generation infrared sensors can detect a user's presence from a distance of 50 cm (approximately 2 feet). This sensing range can allow a thermostat to change what it displays based on whether the user is near or far from the unit. For example, when a user is within 50 cm of the thermostat, the display might show menu buttons along with the temperature. When the user is farther than 50 cm away, the entire display area can show a larger font of only the room temperature so that the user can read it from across the room.

By using multiple infrared LEDs and detectors, a system can support a touchless gesture interface. Depending on the sensing system's configuration, it can detect coarse movements of the user's hand in multiple directions. This capability could allow users to use touchless scrolling when using a cooking application on a mobile device to advance to the next step even though their hands are covered in oils or messy food materials.

"Infrared systems will not replace existing interface technologies," says Ahsan Javed, human-interface-product manager at Silicon Labs. "Rather, they can be used to augment the current sensing systems." Such augmented devices can act with more certainty to improve the system's performance, battery life, and the user's experience with the device without requiring the user to be aware that the system is automatically adjusting many small details.

Dual-core gyroscopes

Gyroscopes and accelerometers are enabling new and expanded capabilities that are both visible and invisible to the end user. MEMS accelerometers and gyroscopes are replacing bulky sensors that comprise discrete components in applications such as air-bag-deployment systems for automobiles in smaller form factors and at lower costs. Since 2003, accelerometers have been used in disk drives to detect when they are falling. During the fall, the drive attempts to lock the mechanical portions of the system into a safe place to protect the drive mechanism and the stored data before the drive collides with the ground or another surface.

As designers incorporate better motion-sensing technology in smartphones and tablets, the applications on these devices will begin to go beyond display rotation based on the orientation of the device. Mobile systems are increasingly able to support pedestrian-level dead reckoning to assist with indoor and multiple-floor navigation. The systems detect motion well enough to support enhanced motion-based gaming, and designers are experimenting with replacing handheld devices' ability to react to pushed buttons with the ability to instead react to motions or gestures. For example, a designer might remove the mechanical power-on/off button when the system can reliably detect when the user performs a custom motion with the device.

The three- and six-axis MEMS accelerometers and gyroscopes enabling these capabilities sell for less than $1 and $3 (large quantities), respectively. The recently announced MEMS L3G4IS dual-core gyroscope from STMicroelectronics sells for less than $4 (1000). The dual-core gyroscope recognizes user motion and supports camera-image stabilization and a motion-sensing range of 65 to 2000°/sec. Sensors with a range of 65°/sec can detect small motions, such as those in optical-imag--stabilization systems. The systems must sense and compensate for jitter in a user's hand to capture clear images. The ability to sense, say, 2000°/sec motion enables systems to accurately detect fast and broad motions, such as when a user performs swings at a ball during a game. As designers continue to find effective ways to use advanced motion sensing, they may be able to use nine- and 10-axis sensors, adding three axes of magnetic sensing and barometric/altitude readings. Such devices include STMicroelectronics' iNemo inertial modules.

The opportunities for hidden-interface innovations are virtually endless; nearly every application can perform better if it can adjust its behavior to a user's intended and unintended usage patterns and can mitigate and compensate for undesirable patterns without requiring users to modify their behaviors. The future looks bright for smarter appliances and products that can adjust to their users through hidden interfaces rather than requiring the user to adapt to the appliance.

Reference

1. Koprowski, Gene J, "2012 and the Technology Blahs," Fox News, Dec 27, 2011.

Author's biography

Robert Cravotta is principal analyst and co-founder of Embedded Insights. He previously was a technical editor at EDN*, covering embedded processors, and worked in aerospace on electronics and controls for pathfinding projects, such as fully autonomous vehicles, space and aircraft power-management systems, and Space Shuttle payloads, as well as building automation systems. Cravotta received a master's degree in engineering management from California State University—Northridge and a bachelor's degree in computer-science engineering from the University of California—Los Angeles.*