Innovating Sensors for Future Smartphones

Sensing is the key function in smarphone today and it is the emergent theme in the next wave of mobile UI innovation.

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A decade ago, our mobile phones were barely phones. We made phone calls and sent text messages. That's pretty much it was. Nowadays, smartphones are increasingly a computer: high-speed internet connectivity, Gigabytes of storage, and a processor that is comparable to that of a supercomputer in the 70s and that of a laptop a decade ago. They allow us to browse the web, play games, watch TV, listen to music, take pictures, and manage contacts and so on. What an achievement by computer science and electrical engineering!

Sensing as a key function

The next decade may see a paradigm change. The next wave of mobile applications should be able to serve us continuously without our active engagement. As we carry them along, they collect data, analyze situations, and provide information in situ, as a human companion would do. For example, they will add an entry to the calendar when they hear the user agrees to a meeting with a colleague.

User can definitely like to use such a smartphone. There are a few interesting research challenges, however. First of all, the platform architecture of smartphones must be reconsidered to add sensing as a key function. This is because their services will increasingly rely on how well they know about the user and the user context. The platform architecture should be redesigned to embrace sensors with diverse natures, deviating from the current computing-centric paradigm. Moreover, smartphones should be able to seamlessly work with wireless sensors worn by the user, implanted inside the user, or even deployed in the environment to collect data. Coupled with the almost unlimited computing power from the cloud (e.g. data centers and server farms), available to smartphones through wireless connectivity, the capability to see, hear, feel, and even smell continuously will make our smartphones truly like a human companion.

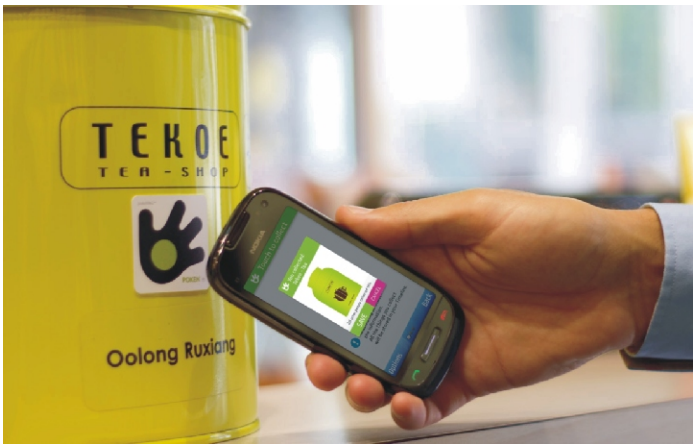
The tremendous growth of sensor technology in

The introduction of more capable smartphones and tablets has led to more advanced processors, high definition screens and a variety of sensors, designed to make these devices "smarter." Notably, smartphones and tablets now universally include some combination of an accelerometer, magnetometer and gyroscope, to enable a wide range of motion aware and motion controlled applications, and this trend is expected to grow dramatically.

Smartphone increases day by day and will experience fabulously over the next few years. Success of smart phones is leading to an increasing amount of MEMS & sensors in mobile phones to provide new features/ services to end-users, to reduce cost through more integration or to improve hardware performance.

Ambient light (ALS)

An ambient light sensor to portable devices such as tablets, smart phones, and laptops extends battery life and enables easy-to-view displays that are optimized to the environment. According to the



spectral sensitivity of light measurement in human eyes, modern ambient light sensors attempt to live with an incomplete match to the photonic CIE curve, "Ambient-Light Sensing Optimizes Visibility and Battery Life of Portable Displays". And instead use the principle of superposition to calculate the ambient light brightness. Most light sensors on the market today use two or more different types of photodiodes, each sensitive to a different portion of the light spectrum. By combining these photodiode outputs mathematically, each with a suitably adjusted gain, the sensor can be made to output a fairly accurate measurement of ambient brightness for the light sources commonly available. However, basically an ambient light sensor adjusts the display brightness which in turn saves battery power in Smartphone; it saves power by adjusting the brightness of the display based on how much ambient light is present.

Proximity Sensor

A proximity sensor is very much useful in Smartphone. It detects how close the screen of the phone is to your body. This allows the phone to sense when you have brought the phone up to your ear. At that point, the display turns off in order to save battery. It also stops detecting touches, as to avoid unwanted input, until you take the phone away from your ear. Proximity Sensor can turn off the screen to avoid accidental touch of the screen by ear. Besides it is useful for detecting towers and sources of interference. So that one can amplify or filter them out using beam forming techniques or others. In the case of iPhone, the proximity sensor shuts off the screen and touch-sensitive circuitry when the iPhone is brought close to the face, both to save battery and prevent unintentional touches. So in a word, The proximity sensor in Smartphone senses how close the phone is to the user's cheek/face, so that it can pause whatever activity it is in the middle of (playing music or browsing the web, for example) so the user can take a phone call. When the phone is removed from the ear after the call, the phone resumes its previous activity.

Global Positioning System (GPS)

GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. It's a Navigation tracking, often with a map "picture" in the background, but showing where you have been, and allowing "routes" to be preprogrammed, giving a line you can follow on the screen of Smartphone. GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the user's exact location. As an example, iPhone models use A-GPS — or "Assisted GPS" — which in basic terms accesses an intermediary server when it is not possible to connect directly via satellite — indoors, for example — and this server provides the nearest satellite with additional information to make it possible to more accurately determine a users position. The iPhone 3G, 3GS and 4 employ A-GPS, and the iPhone 3GS and 4 also have a digital compass. iPhone 4S supports GLONASS global positioning system in addition to GPS.

Accelerometer

The accelerometer allows the device of Smartphone to detect the orientation of the device and adapts the content to suit the new orientation. For example, when you rotate your device sideways, the Web browser automatically switches the screen to landscape mode so that you now have a wider viewing space. Similarly, the camera relies on the accelerometer to tell it whether you are taking a picture in portrait or landscape mode. The accelerometer in smart devices measures the acceleration of the device relative to freefall. A value of 1 indicates that the device is experiencing 1 g of force exerting on it (1 g of force being the gravitational pull of the earth, which your device experiences when it is stationary). The accelerometer measures the acceleration of the

device in three different axes: X, Y, and Z. As an example of this sensor in iPhone, it says - A 3-axis accelerometer senses the orientation of the phone and changes the screen accordingly, allowing the user to easily switch between portrait and landscape mode. Photo browsing, web browsing, and music playing support both upright and left or right widescreen orientations. Unlike the iPad, the iPhone does not rotate the screen when turned upside-down, with the Home button above the screen, unless the running program has been specifically designed to do so. The 3.0 update added landscape support for still other applications, such as email, and introduced shaking the unit as a form of input. The accelerometer can also be used to control third-party apps, notably games. The iPhone 4 also includes a gyroscopic sensor, enhancing its perception of how it is moved.

Compass

Basically compasses are attracted to the earth's poles using magnets. But the modern smart phone is not using magnets. Magnetic interference would render the Smartphone's cellular capabilities useless. Once introduced, magnetic interferences drops signal strength parabolic ally. Frequency and ranges are consistent with GSM bands. As an example, the AK8973 chip on the iPhone is a small sensor that "listens" for an ultra low frequency signal. If that signal comes from a specific spot like North, paired with the accelerometer the device can calculate the orientation and direction. The compass in the iPhone 4 is the AKM AK8975, which is very similar to the AKM AK8973 in the iPhone 3GS. It senses orientation relative to the Earth's magnetic field using the Hall Effect. The Hall Effect occurs when a magnetic field is applied transverse to a flowing current. The magnetic field deflects the moving charges that make up the current, inducing a voltage (called the Hall voltage, shown in the figure below as) that is transverse to the current. The Hall voltage can then be measured and used to determine the strength of the component of the magnetic field that was transverse to this current.

By using multiple sensors oriented in different directions, and by using a disk of high permeability material called a magnetic concentrator to bend magnetic field lines that are parallel to the sensor plane so that they have a component perpendicular to the sensor plane that can be sensed, the device can measure the total magnetic field vector and therefore determine the device's orientation relative to that magnetic field.

Gyros

A gyroscope is a device for measuring or maintaining orientation, based on the principles of angular momentum. Gyroscopic sensors used in navigation systems and gesture recognition systems in Smartphones and tablet PCs. Gyroscopes are used in Smartphones and tablet PCs for finding the position and orientation of devices. Wireless computer pointing devices such as mouse for controlling the mouse pointer based on wireless mouse movement. A group of researchers says – Earlier this year the iPhone 4 became the first Smartphone to boast a built-in gyroscope in addition to an accelerometer, proximity sensor and ambient light sensor. Combining a gyroscope with an accelerometer allows the device to sense motion on six axes – left, right, up, down, forward and backward, as well as roll, pitch and yaw rotations – allowing for more accurate motion sensing abilities comparable to a game controller such as the Wii-mote. The iPhone 4 uses a MEMs (micro-electro-mechanical-systems) gyroscope but a newly developed optical gyroscope, small enough to fit on the head of a pin, could allow the integration of more accurate motion sensing technology in not only smartphones, but also in medical devices inside the human body.

A New Sensor – (Back-illuminated sensor)

A back-illuminated sensor, also known as backside illumination (BSI or BI) sensor, is a type of digital image sensor that uses a novel arrangement of the imaging elements to increase the amount of light captured and thereby improves low-light performance. The technique was used for some time in specialized roles like low-light security cameras and astronomy sensors, but was complex to build and required further refinement to become widely used. Sony was the first to reduce these problems and their costs sufficiently enough to introduce a 5 Mpx 1.75 μm BI CMOS sensor at general consumer prices in 2009. BI sensors from Omni Vision Technologies have since been used in consumer electronics from other manufactures such as HTC's EVO 4G, and as a major selling point for the camera in Apple's iPhone 4. A back-illuminated sensor contains the same elements, but orients the wiring behind the photocathode layer by flipping the silicon wafer during manufacturing and then thinning its reverse side so that light can strike

the photocathode layer without passing through the wiring layer.
As we see the application and programs of sensor technology in most smartphones increase geometrically, this rapid growth may give us a new direction of a smart planet in our hand.

A taste of feature innovation

Innovation in the handset manuafcturing is the challenging job for major OEMs. Feature innovation comes today in many forms, as manufacturers try to evolve smartphones into smarter phones; haptics, predictive texting, gesture recognition technology, inertia sensors, digital compasses, and the emergence of pico projectors to name a few.
- Next Generation Haptics: Haptics, or the process of using motion or vibrations to create tactile feedback on a users hand or finger, has been around for quite a while, with solutions available from Immersion and Synaptics. As an alternative to using touch-sensitive screens, companies like eyeSight and GestureTek are using the built-in phone camera to analyse hand motions and recognize gestures.
- Inertia and direction sensors: handset makers are following Apple's lead with the integration of accelerometers, digital compasses and gyroscopes into the phone. These sensors can be leveraged to support for example improved location through dead reckoning and gesture recognition. Gyroscopes and compasses are also providing precise data on the location of a device in the three dimensional plane opening the door to augmented reality applications. Companies such as Layar and Wikitude are helping developers walk through that door with AR software platforms.
- Predictive Text & Gesture Tracking: Predictive texting has seen limited innovation beyond plain-old T9; as such a range of vendors have emerged to provide significant improvements in prediction and correction accuracy, namely Keypoint, EXB, TouchType, Cootek, Keisense (now Nuance) and BlindType (acquired by Google). New forms of predictive texting combined with gesture recognition technology such as as Swype and ShapeWriter (acquired by Nuance) is enabling quicker text input on a touchscreen – for example tracking the movement of a finger on a touch screen, a phone moving in space with inertia sensors, or tracking hand movements with infrared technology hand gestures.
- Pico Projectors: While the integration of pico projectors, or mini video projectors, into mainstream phones is still a ways off, the technology from the likes of TI and Micorvision claims to overcome one of the biggest UI challenges of mobile device, small screens.

Integration challenges

As easy as it may sound, innovative features are not just about shopping components off the shelf. Cost is an important consideration, especially for technologies that require specialized components that do not enjoy economies of scale.
Integrating new technologies into handsets is a further challenge for handset designers. Digital compasses are sensitive to electronic interference and need to be carefully positioned within the phone to avoid interacting with neighboring electronics. The design of haptics mechanisms also presents many problems. In a typical haptics system design, touch screens float in their frames and are held in place by flexible materials that allow the screen to vibrate creating haptics effects. These designs can fail letting dust inside the device or the screen can separate from the frame if the device is dropped. OEM's are still learning how to effectively incorporate such features into their designs.
A number of start-ups are working on overcoming these barriers in addition to creating new capabilities. Innovation of course requires risk-taking. OEMs are finding themselves in a chicken and egg scenario; design cutting edge features first, or wait for the apps to leverage the features? Samsung and HTC seem to be comfortable taking such risks. Samsung was the first to introduce a phone with an integrated pico projector in 2009 and the Galaxy S sports a gyroscope, Swipe technology and an Augmented Reality browser. HTC is also pushing the envelope having developed and launched devices with home grown haptics.
Undoubtedly users will be the biggest winners as OEMs battle to wow new customers. A close second will be application developers who will stretch their imagination to build new applications and businesses around emerging features. While these opportunities are compelling, progress will not happen overnight. Gyroscopes are still only available in high end smartphones and next generation haptics will only appear in niche devices next year. If you're interested in building an app for a pico projector, you may be waiting a few more years.