Innovations in Ubicomp Products

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Phones and MP3 Players as the Core Component in Future Appliances

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ONE MOTOR AND FIVE DEVICES

In the 1980s, we used power toolsets that consisted of five or six power tools but were delivered with a single motor attachable to each of the tools. The tools themselves were motorless. At the time, the rationale for this design was twofold: the motor was an expensive component and not replicating it saved money, and people did not need both their circular saw and their power drill at the same time. This approach has a long tradition and was also common, for example, with early electric kitchen appliances.

Such systems have become uncommon. However, looking at current consumer electronics it seems that a similar trend might be emerging. This time the expensive and complex components are the user interface and the embedded processor. Hence, this component is shared among appliances.

STANDARDIZED COMPONENTS

In mechanical and electrical engineering, standardizing components, making them cheap and readily available, increased people's ability to construct and build devices quickly. This approach lowered the overall costs—for development, production, maintenance, and repair. As an example, in mechanical engineering, your calculations will tell you that the screw you need in your design must be 6.4 millimeters in diameter to support the task. When implementing your design, the engineer will use an M8 screw (a standardized screw that is 8 millimeters in diameter) without thinking. The idea of designing and manufacturing a screw with a 6.4-millimeter diameter won't even be considered. In these disciplines, it is most common to use standardized components—from small components such as screws and washers to complex components such as engine parts and car tires. A further benefit of using standardized components is that you can use standardized tools. For an M8 screw, you will find a spanner in any toolbox; in contrast, if you design and manufacture your own 6.4-millimeter screw, you must also build tools for it.

(ELECTRONICS) DEVICES ARE COMPUTERS

Progress usually converts consumer electronics, kitchen appliances, and electronic tools from mechanical, electrical, or electronic devices to special-purpose computers containing extended input and output capabilities. Multimeters, personal video recorders, heating controllers, music players, and high-end sewing machines are essentially computers with very specific sets of inputs and outputs (see Figure 1). For the sewing machine, certain patterns can be programmed. A heating controller is connected to the sensors and actuators in a house. Typically, the core expertise of manufacturers of these goods is in the part of the device that surrounds the computer. Consider manufacturers of power measurement tools; their expertise and experience are typically in how to measure power and analyze the sensor reading.

Nevertheless, current developments increasingly demand that manufacturers become computer technology companies as building the devices essentially means building a computer at their core. Figure 2 shows the evolution of multimeters. Some years ago, building these devices was fairly simple because the computer was based on a microcontroller and the user interface consisted of an LCD display and a few buttons. Over time, expectations increased. Today, customers expect from their multimeter a user interface with an iPhone-like experience as well as means to record their measurements online. Many of these companies have put significant effort in developments that are outside their core business and expertise. This is a major issue especially for companies that produce small quantities.

PHONES AND MP3 PLAYERS AS STANDARDIZED COMPONENTS?

Looking at the variety of mobile devices (especially MP3 players and phones) that have become available in the last two years, we like to ask the

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questions: Will mobile devices become the standardized computing component for the next decade? Will mobile phones be OEM products that become parts of other goods? Figure 3 shows a selection of devices that share two essential features to enable this:

- They are programmable, and distribution channels for the software exist.
- They have I/O channels that allow them to link to external devices.

The variety of available devices, especially for the Android platform, is massive. Hence, many designs will likely include a mobile device whose size, processing power, and user interface capabilities can realize the requirements of the "computer." There are essentially two approaches to using mobile phones and MP3 players as computing components: in one, devices are sold as accessories to the phone; in the other, the phone becomes a part of the device. Examples for the first one can already be found in the market; for the second one, we have not have seen examples yet.

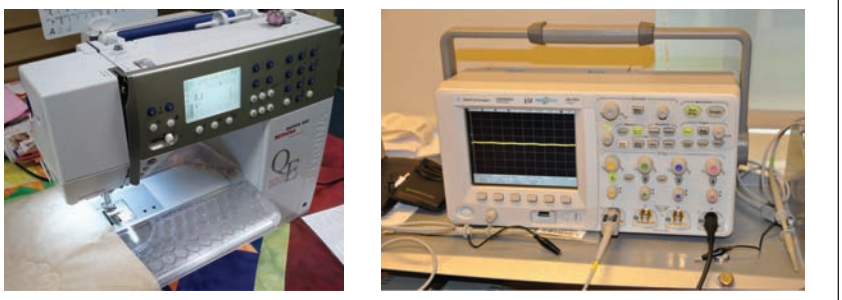

Figure 1. Product pictures: (a) a sewing machine with a large display and (b) an Agilent oscilloscope with a color display.

Figure 2. Evolution of a multimeter: an analog multimeter (left), a multimeter with LCD display (middle), and a multimeter with large screen display and analysis functions (right).

DEVICES AS ACCESSORIES TO THE PHONE

Treating a device as an accessory is the most common approach because it follows the idea of the exchangeable motor. The device manufacturer creates the device-specific hardware and sells it as an accessory to a phone. Examples include an attachable blood pressure measuring device for the iPhone,[1] a car entertainment system that is essentially a dock for the phone,[2] and a credit card reader that can be attached to the iPhone.[3] Such an approach is not entirely new; people tried it when the Gameboy was popular (for example, as an accessory for measuring blood sugar[4] and a multimeter [see http://sites.google.com/site/kenselectronicsprojects/gameboy-analog-meter]).

Passive components are another domain of accessories that only changes the device's form factor. This approach has been successful in the last few years with the Sony Wii controller, which offers everything from a steering wheel to a guitar and a tennis racket (see Figure 4). The Birdbox alarm clock (www.luckybite.com/luckybits) is conceptually similar. It is a cardboard box in the shape of a birdhouse with a circular cut-out and an application that runs on the phone. As Figure 5 shows, the cut-out displays the phone's screen, which is either the clock face or a view into a virtual bird nest. It is extremely low tech, but it transforms the phone into a different device.

MOBILE DEVICES AS A PRODUCT COMPONENT

As mass-produced mobile devices continue to become cheaper, they could increasingly serve as a component in a product. For the sewing machine in Figure 1, for example, we could imagine replacing the color display and custom computer with a programmable touch-screen MP3 player or phone. The casing design and custom software could hide the commodity device so it would be hard to see without dissembling the sewing machine. Using off-the-shelf devices as the core computing

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Figure 3. Different form factors of devices that could become components for creating interactive devices: (a) iPod Nano, (b) a Samsung Android phone, (c) a Windows 7 Phone, and (d) a Galaxy tablet running Android.

Figure 4. Wii controller accessories. You can transform the functionality by adding passive parts to an electronic device.

component could significantly reduce the development effort of the appliance's computer parts and hence could allow more people to create sophisticated appliances. The skill sets required are programming a standard platform and electromechanical design, but not hardware development. Combined with 3D printing, this approach could broaden the set of people who could produce and distribute complex appliances.

CONNECTING DEVICES AND PROGRAMMING

The remaining central issue is how to connect phones and MP3 players to custom devices and accessories. Different approaches exist but, so far, manufacturers do not provide much support or even make it deliberately hard to extend the I/O capabilities.

Audio is the ubiquitous, cheap, and least-restricted channel available on nearly all devices. Assume you want to design a device that has a user interface for controlling actuators, for example, thinking of the sewing machine again. You could encode the control commands in an audio stream. The only part that would need to be developed then is a circuit to convert the audio signal to digital information. If the device also supports audio in or includes a microphone, the audio communication can be two-way. The implementation is basically a modem, but the bandwidth is limited. Project HiJack (www.eecs.umich.edu/~prabal/projects/hijack) is an example implementation. However, for typical applications controlling electromechanical devices, this is more than sufficient. A credit card reader is another example of this approach.

Many other options for linking devices exist: device-specific connectors, USB ports, wireless connections, and so on. They offer much higher bandwidth, but the specifications have changed much more often than those for the headphone/microphone channel. Currently, by committing to a certain connector, you commit to a certain

device, unlike when using the audio channel, where the headphone connectors are ubiquitous.

In contrast to developing for a custom embedded system, programming for a standard mobile phone platform is much cheaper and easier—given the large developer community, extensive tool support, and numerous libraries.

THE PHONE AS AN ACCESSORY

The Chinese company Yosion's Apple Peel 520 (www.peel520.net) follows this same philosophy—Yosion started with a comparatively cheap commodity device and created an appliance by adding an accessory. The device is a bumper shell (which we all know from the iPhone 4) that adds basic phone and SMS capabilities to an iPod touch. The bumper shell includes a complete mobile with a battery but has no display or keypad. It does not convert the iPod into an iPhone, but it creates an interesting device symbiosis with added value for users. In this example, too, programming the connectivity is a major issue—the Apple Peel 520 requires that the iPod is jail broken, which means that a device is hacked to allow third-party installations.

Apple probably has little interest in supporting this extension of the iPod touch. In general, however, it is a good idea to open up platforms for other developers to build upon. If manufacturers actively support the concept of the phone as a core for future consumer products, we might experience an effect similar to what we saw when Apple opened up the phone platform to a large developer community and provided easy means for creating and distributing applications.

The main hindrance to a more widespread adoption of the approach we've described is the lack of an easy means for interfacing external components, especially sensors and actuators. Such interfacing requires both hardware to provide physical connectivity and an easy means of programming that integrates well with the available software infrastructure. Developers must be able to interface and extend the hardware within the legal framework of developing applications. P

Figure 5. The BirdBox alarm clock. A cardboard casing transforms the iPhone into an alarm clock. (Photo used with permission from luckybite.com.)

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