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Viewpoint
Wearables: Has the Age of Smartwatches Finally Arrived?

Time will tell if smartwatches will find their niche.

IMAGE BY MARK PRINCE

THE IDEA OF strapping a computer to one's wrist is not new. By the middle of the 20th century there were plenty of examples of this in science fiction and the 1970s saw the first LED and LCD watches such as Pulsar NL C81. Intel's Gordon Moore famously bought the Microma digital watch company, hoping to develop a more powerful wrist-mounted computer. However, the technology was expensive at the time and not powerful enough to provide much more functionality than non-digital watches. Therefore, similar efforts, such as the Fossil wrist PDA and IBM/Citizen WatchPad also failed.

In the last century, the wristwatch replaced the pocket watch as a more convenient place to get at time information quickly. More recently, the ubiquity and functionality of mobile phones (which can also display the time) caused many to abandon the wristwatch as redundant jewelry and go back to what is effectively a pocket watch.

Now after more than 40 years of technological improvements, smartwatches seem to be heading in the same direction as mobile phones: multiple functionalities. Smartwatches are not only a chronograph, but can also be a general-purpose, networked computer with an array of sensors. Moreover, they have followed a familiar pattern in technological trends: the concept has been around for long time, but it took longer for the technology to advance enough for proper implementation. Recent advances in miniaturization and diminishing costs in battery, processor, sensor, and communication technologies are now enabling smartwatches to move from the specialist market to the mainstream.

To gain an overview of the research potential and technological impacts of these devices, we provide a brief description of the current market. Based on the current market status, literature reviews, and reviews of smartphone technology, we can identify both restrictions and advantages of smartwatches—and from this highlight the research challenges and opportunities associated with smartwatches.

Market Demand and Direction

In May 2012, the Pebble watch designers had one of the most successful campaigns in the history of crowd funding at the time.[a] The Pebble story is evidence of a huge market demand for such technology. Generator research predicts this market will grow to 214 million units by 2018.[b]

The Pebble is not the first modern smartwatch; it was preceded by Sony's SmartWatch. However, because Sony's device relied on its Bluetooth connection to act as a complementary interface to compatible Sony smartphones, the Pebble could be considered the first fully independent smartwatch.

Large-scale consumer electronics manufacturers have begun to release their own smartwatches or define specifications for their future smartwatches.

a See http://kck.st/18KLHqM
b See http://bit.ly/1ybRoEm

Some, such as Samsung and Sony, have started to launch smartwatches as a complementary interface for their mobile devices (smartphone or tablet) while others are adopting a hybrid approach. For example, the Android Wear watch requires an Android phone to install apps, but the watch can then operate independently without a smartphone connection. Both the Apple Watch and the Microsoft Band also function independently of a smartphone but make use of a smartphone for some communications. It may be too early to judge if smartwatches are truly independent computing devices, or if their restricted capabilities and competition in the market make them little more than remote interfaces or limited-function fitness devices. Nevertheless, this property provides a crucial focus for analyzing their constraints and advantages.

Constraints

Smartwatches suffer from two major constraints to do with keeping them small enough to wear on a wrist: their small screen size results in restricted I/O and their small hardware results in weaker computing capability and especially limited battery capacity in comparison larger devices. Although mobile devices have advanced in recent years, the challenge of reducing size while maintaining features and battery life continues.

The small screen size restricts input and output capabilities. For instance, fitting a keyboard on a smartwatch screen or wristband is even more challenging than fitting one on a smartphone. Although there have been efforts to enable smartwatches to display multimedia, their small screen size makes them a poor choice as a media player for video or images. Micro projectors are a tantalizing solution, but several years after their announcement they are still too expensive to consider, and thus wearable projectors[3] do not seem to be a realistic prospect in the near future. A larger screen, which can be achieved through curving the screen around the wrist, seems to be an option to begin to address the size issue, but still not enough for keyboard integration. Several brands, such as LG, have launched their curved screen for TVs and Samsung also recently released Samsung Gear S smartwatch with a curved screen. Most traditional watch screens are lightweight, waterproof/resistant and antiscratch. How well curved screens maintain these characteristics remains to be seen. The screen restriction will also require fresh thinking on user interface (UI) designs and for new interaction techniques such as 3D ultrasonic gesture recognition.[c] Google's Andriod Wear relies heavily on voice input for simple user interaction but this may restrict users to performing more complicated tasks.

Smartwatches have two strong advantages over other devices: their mount location and (probably more important) the continual connection to the skin.

Small hardware means less computing power, smaller battery capacity, and less-precise sensors. These challenges exist in smartphones as well as smartwatches, although to a lesser extent. Software and hardware providers have been working, slowly but continuously, to address resource-related issues. For example, GPS systems typically have a high power requirement. Localization services try to overcome this problem by relying on a combination of sensors such as GSM, Wi-Fi, and GPS—hence reducing the power consumption.

Although hardware components get smaller through advances in sensor technologies and electronics,[7] the smaller footprint means smartwatches have fewer ubiquitous computing features compared to smartphones. Most of the smartphone-dependent smartwatches overcome this by offloading power-consuming sensing and computing operations to the phone and use low-power Bluetooth to communicate. This enables smartwatches to communicate with the smartphone and to rely on its superior computing capabilities. This way, power-hungry chips such as GPS can draw on the larger battery of the phone and simply use the watch as a convenient user interface, but the phone still has most of the "smarts." The fully independent smartwatches, which incorporate their own 3G or GPS chips, tend to have a much shorter battery life.

Advantages

On the other hand, smartwatches have two strong advantages over other devices: their mount location, and (probably more important) the continual connection to the skin. Similar to augmented reality glasses, their interactions do not always require both hands. In particular, users do not need to hold the device, which is required by smartphones and one hand is completely occupied. Nevertheless, users need to change wrist position and, if a touch or voice input is needed, use the other hand for the interaction.

Smartwatches are body mounted, with a standard, known location. This helps activity recognition research by removing the burden of identifying the location of the device. Much research has been done to quantify health information via mobile devices (mHealth). The standard location overcomes challenges associated with smartphones; for instance, when measuring users' activities based on accelerometer data, the location of the smartphone (if in a shirt pocket, in a bag, or in a trouser pocket) affects the data.

A smartwatch is typically in constant contact with its owner, and thus capable of recognizing its owner's physical activities and location. In contrast, a limitation associated with smartphones is that, when users are not holding them, they can sense only the users' environment (outward) and not the users' specific condition (inward). When smartphones are carried, they are in various locations in bags and pockets. Often, in an indoor environment such as an office or home, a smartphone is not moving and may not be co-located with its owner. The smartwatch's continual connection to the skin could revolutionize mHealth studies. Enterprise vendors recognize this and are already including slots for this data in their health kit toolsets, such as Google Fit,

c Chirp gestural interface: http://bit.ly/1zM3tSP

Apple HealthBook, Samsung S.A.M.I, and Microsoft Healthvault.

The location also permits easy recording of heart rate, heart rate variability, temperature, blood oxygen, and galvanic skin response (GSR). GSR can be used to identify physiological arousal, especially when combined with heart rate and heart rate variability. Emotion has two dimensions: mood valence (positive vs. negative) and arousal (high vs. low).[4] Automatic emotion quantification approaches (except those based on image recognition) are restricted to arousal and not valence. Therefore, in order to collect valence, existing affective recognition systems rely either on image recognition or manual user input. Because user input is subjective, its accuracy is often questioned. With the advent of smartwatches and effective multisensor data collection, we might develop algorithms (for sensor data fusion) that can identify valence without the need for processing a facial image.

Research Opportunities and Future Visions

Based on the constraints and advantages discussed, we can identify several research opportunities for advances in smartwatches.

- Battery life and cost are probably the most important success factors for smartwatch acceptance in the market. The failure of Microsoft's SPOT (Smart Personal Object Technology),[1] because of cost and battery limitations, and the delays in Apple's Watch release show the importance of considering these two factors. The challenge of optimizing resources, especially power, is an ongoing research topic. This is a multidisciplinary challenge. End-user applications, internal hardware (lightweight battery, hardware miniaturization) and external hardware (wireless inductive charging or substituting lithium-ion with other materials such as solid electrolytes) could be investigated further. Research on harvesting kinetic motion and body heat for electricity generation could also have an impact. However, device makers continue to focus on reinventing the battery and its charging process, such as charging wirelessly with magnetic induction. We have yet to see any revolutionary improvements.
- Smartwatches could be a significant boon to mHealth technologies. Physical activity sensing is already being used in many smartwatches and fitness trackers, such as the Nike+ SportWatch, Fitbit, JawBone, Basis, and Microsoft Band, to persuade users toward a more active lifestyle. Smartwatches could also host more bio-sensors and take more accurate measurements than the simple accelerometer-based wristbands. Algorithms that focus on energy-efficient activity recognition and convert raw biological data into higher-level data will need further development.
- With capability comes responsibility. Smartwatches can easily sense and record most private information such as sexual activities, sensitive medical information, and knowledge of the owner's fundamental weaknesses. Given the potential of smartwatches to sense and record individuals' behavior and physiological responses, maintaining the privacy of this information is another research challenge.
- Existing smartwatches have very small touchscreens with no or few buttons on the side, suggesting the need for new interaction techniques such as voice, haptic, gestural interfaces, projection, and near-field communication (NFC). Some brands, such as Android Wear, provide highly reliable voice commands for interaction. Some other brands are working on interaction through the accelerometer as well as haptic feedback. Therefore, it is likely that new interaction algorithms and also new UI patterns will be introduced, and existing approaches will be optimized toward better precision on a small screen and lower resource usage. For smartwatches that are smartphone dependent, interaction techniques are distributed between both the devices, for example, supporting keyboard input via the smartphone and voice input via the smartwatch.
- There are many discussions about the negative effect of new technologies on memory,[2,5,6] and smartwatches are another attention- and cognition-consuming device. Although it may be that their restricted I/O capabilities will prevent users from interacting with them too much, their impact on activity and memory and cognition is still an open question to explore.
- What is the best operating system for smartwatches? Some vendors such as Samsung and Qualcomm launched their first devices with the Android OS and WIMM lab was developing Android- based smartwatches before Google acquired them in 2012. Google released a lighter Android version, Android Wear, for smartwatches and other wearables. Although Android is currently the most popular OS for smartphones, it is clear that an optimized OS is needed for smaller devices. Samsung is using a wearable-optimized OS, Tizen, for some of their wearables. Apple and Microsoft have taken a similar approach in creating a new OS for their wrist devices. Clearly there are research opportunities for OS developers to either create a new OS distribution or customize an existing one to make it light enough for smartwatches.

Smartwatches are likely to find their own place in the market. Just as tablets have not replaced the laptop and smartphones have not replaced TV remotes, so smartwatches may find their niche without replacing other devices. A new arena for pervasive computing research is emerging, one that is likely to attract many researchers and entrepreneurs, with interests from data analytics and self-quantification to hardware design, human interfaces, and manufacturing. C

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