The New Wearable Computing Frontier

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Driven by advances in mobile computing and communications, ambient intelligence, and ubiquitous sensors, wearable computing facilitates a new form of human-to-computer interaction via small, on-body devices that are always connected, hands-free, and less distractive, and that have multiple access opportunities. This always-ready capability leads to a new form of synergy between humans and computers, offering consistency and multitasking capabilities.

What Is Wearable Computing?

According to a 2015 wearable technology and markets report,[1] there are two main types of wearable technologies:

- Apparel and textiles are used in healthcare, medicine, sports, safety, and fashion for fitness, wellness, and life-tracking applications. They also apply in industrial, police, and military environments (for instance, hand-worn terminals, body-mounted cameras, or augmented-reality headsets). The technology is disruptive and has closely integrated electronics.
- Devices for infotainment include smart watches, augmented reality headsets, and smart glasses. The technology is mainly integrated into conventional electronics and is evolutionary—that is, it combines mobile phone peripherals or variants of new human interfaces with diagnostic devices.

The rich variety of today's wearable technology applications is nicely depicted by Beecham Research (see Figure 1; an interactive version is available at www.beechamresearch.com/article.aspx?id=20).

Market Growth Forecasts

Market forecasts and the adoption of wearable computing suggest significant growth. Juniper research predicts that smart wearable device shipments, including watches and glasses, will exceed 100 million by 2017, and that the smart wearable market will generate US$53 billion in hardware revenues by 2019 (http://tinyurl.com/pumlb2z). ABI Research forecasts that the global wearable computing device market could reach 170 million devices by 2017, assuming the entry of most of the major platforms, including Google, Microsoft, and Apple.[2] The highest growth areas are sports and activity trackers, but wearable computing will eventually fully integrate into our

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Figure 1. World of wearable technology applications. (Figure courtesy of Beecham Research; see the interactive version at www.beechamresearch.com/article.aspx?id=20.)

clothing, becoming seamless and invisible.[3] According to Forbes, 71 percent of 16- to 24-year-olds want wearable technology (http://tinyurl.com/pw3268l).

From Past to Future Wearable Devices

Figure 2 displays the profound importance of wearable devices in different aspects of our society from the past to the present and beyond. In 1945, Vannevar Bush's "As We May Think" proposed the first wearable device with augmented memory. During the 1960s, many of the designs were analog and used in casinos. Ed Thorp and Claude Shannon invented the first wearable computer to predict the outcome of spinning roulette wheels.[4] Evan Sutherland used a head-mounted 3D display presenting images in 1968. The first algebraic calculator watch was designed by Hewlett-Packard in 1977. Through the years, wearable computers have gotten considerably smaller, although in the 1990s they were still the size of a shoebox. It wasn't until 1999 that Steve Mann's digital eyeglass became the predecessor to Google Glass. It was then that the wearable computer became a mainstream phenomenon.

The Internet of Things (IoT) will drive wearable evolution from now on. Wearable devices are becoming smarter and faster, and have more features. They will affect how we live, work, and socialize. For example, Samsung's Smart Home lets users manage all their connected appliances and devices through a single application. In addition, devices won't need smartphones to operate—other smart wearables will break free of the smartphone link, as with Skinput.[5]

Wearable biosensor systems are expected to be revolutionary in many application areas, such as a sensory vest to allow deaf people to hear the world without vibration. We expect products to

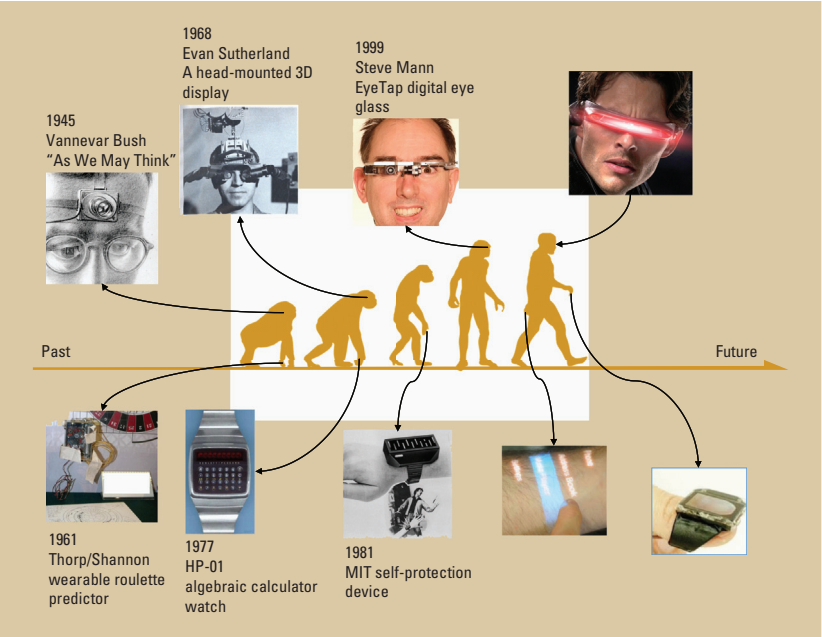

Figure 2. From past to future wearable devices. This figure helps us to recognize the advanced technology and applied sciences in wearable devices.

evolve to improve functionality, reliability, and convenience for digital health.

Human-computer interaction will also play an important role in future wearable technology.[6] NailDisplay is bringing an always-available visual display to fingertips.[7] It will reveal what is occluded under a figure touch and transforms free figure movements into visual output. In the future, fingertips will be able to provide private, subtle, and quick access; like a new kind of Cyclops, we will be able to see everything through a single device.

Challenges and Growth Barriers

Despite the incredible pace of evolution in wearable devices, new challenges such as privacy concerns, data security, service models, product positioning, and marketing pose massive threats to the industry's growth potential.

In 2013, a social study surveyed the impact of wearable technology in the UK and US.[8] The results showed that half of the respondents cited privacy as a barrier to adoption, and 62 percent thought wearable devices should be regulated in some form; 20 percent called for these devices to be banned entirely. Indeed, privacy is one of the key concerns in adopting wearable devices. Data security is also a concern, because large amounts of data are synced to the cloud without underlying security protocols. System designers must consider what external security threats and breaches of personal privacy the system might face.

Device prices and evolving service models are also worries, as are social acceptance issues, such as glass-wear being perceived as more intrusive than wrist-wear, as described by Apple CEO Tim Cook. Wrist-wear seems to be where the money is right now. The choice between standalone (fitness trackers) or integrated devices (smart watches with fitness apps), battery life, and poor data sync functions are device-related concerns as well.

Due to a lack of clear use cases, wearable product positioning is often niche. Early designers lacked experience in fashion marketing, but a wide range of fashion designers and jewelry makers have begun to design wearable technology pieces. Technology and fashion are teaming up to make wearables more fashionable, as featured in Milan's Spring/Summer 2015 Fashion Week or in this CNN piece: http://money.cnn.com/video/technology/2014/09/12/fashion-week-high-tech.cnnmoney/index.html. Wearables such as handbags that can display tweets, bracelets that charge phones, connected rings, and flashing dresses have made their catwalk debut. It looks like wearable technology has finally become fashionable.

In This Issue

This issue of *IT Professional* is devoted to the theme of wearable computing trends, and applications related to the engineering and operational aspects of wearable computing. The articles include a diverse range of sources from Greece, Australia, and Italy. In "The Health Avatar: Privacy-Aware Monitoring and Management," Despina T. Meridou, Maria-Eleftheria Ch. Papadopoulou, Panagiotis Kasnesis, Charalampos Z. Patrikakis, Georgios Lamprinakos, Andreas P. Kapsalis, Iakovos S. Venieris, and Dimitra-Theodora I. Kaklamani show state-of-the-art techniques for seamless discovery and collection of health and lifelog data by a wide range of

wearable devices. The proposed patient-centric care model provides preventative action by analyzing the patient's daily routine and behavior (for instance, health status, environmental or occupational exposure, lifestyle, and diet) with a closer doctor-patient interaction to obtain better health and well-being.

In "Low-Profile Jamming Technology for Medical Rehabilitation," Timothy M. Simon, Bruce H. Thomas, and Ross T. Smith show us that integrating novel feedback mechanisms into wearable devices has the potential to support medical rehabilitation applications and enhance existing methods of interaction. The proposed smart layer jamming wearable prototype provides haptic feedback for interacting with virtual and augmented realities.

Finally, in "Wearable Computing for the Internet of Things," Simone Cirani and Marco Picone propose shaping the Internet of Things (IoT) to provide natural interaction patterns between users and smart objects via wearable devices. The proposed model aims to guide and teach users by increasing their awareness without requiring them to learn new paradigms.

The spectrum of interesting topics in this special issue reflects the multidisciplinary nature of the wearable computing field. Wearable devices will not only be hype; their applications will also play a significant role in our society in the near future. This issue's Spotlight department features "Beyond the Wearable Hype," a discussion by Matthew Lee and Maria R. Lee looking at several new wearable technologies.

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