Implantable Electronics

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The broad vision of pervasive computing is inspired by the diffusion of sensing, computation, and communication throughout our environment. Although most projects focus on smart objects or intelligent environments, our community also encompasses wearable computing, which moves the interface for computational ecology onto our bodies and into our clothing. In recent years, implantable electronics have started to interface with wearable and pervasive networks, hinting at a continuum from intrabody to wearable to ubiquitous systems.

The emergence of new conferences represents this trend. For example, at the Wearable and Implantable Body Sensor Networks workshop (http://bme.ee.cuhk.edu.hk/BSN2008), clinicians join sensor-net, wearable, and ubiquitous computing researchers to explore thematic overlap and inspire cross-fertilization. The ideas coming from this juncture promise to revolutionize many application areas, ranging from healthcare to human-computer interfaces.

Healthcare applications tackle challenges

Despite recent progress, many challenges remain on the road to implanted systems. How do these devices communicate with each other and with wearable devices outside the body? Can they communicate securely to protect privacy-sensitive data? How do they adapt as the mix of devices around them changes? What is their source of power? How do we upgrade their software? What sort of feedback loops must we provide to help users control device functions?

These questions are gaining the attention of researchers in both academia and industry. In these initial growth stages of the field, we're seeing applications focused on healthcare—in particular, on prosthetics, instrumentation, and imaging. New sensors also provide fertile ground for medical monitoring and generating automatic alerts when dangerous situations arise. As wireless communication proliferates, we'll need to consider security issues as well. Even simple denial-of-service attacks take on a whole new meaning.

Eventually, we expect to see implantable devices that not only provide relief from the conditions that might ail us but also offer us new capabilities. For example, in the future, the fully instrumented human will feed a wealth of data to new diagnostic and monitoring systems. Moreover, every person will be part of a detailed clinical database documenting the effects of therapies and medications.

In this issue

The articles in this special issue give a broad snapshot of research in implantable electronics,

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focusing in particular on medical applications of interest to our community.

The first article is "Healthy Aims: Developing New Medical Implants and Diagnostic Equipment," by Diana Hodgins, Arnaud Bertsch, Nils Post, Manfred Frischholz, Bart Volckaerts, John Spensley, J.M. Wasikiewicz, Henry Higgins, Felix von Stetten, and Laurence Kenney. It describes a large EU research initiative that aims to develop and deploy implantable systems for a host of medical conditions under the Health Aims project.

The next article surveys swallowable systems, which might be considered one of the less-invasive implantable systems. In "Swallowable-Capsule Technology," Colm Mc Caffrey, Olivier Chevalerias, Cian O'Mathuna, and Karen Twomey discuss how this technology has evolved over the past decade and describe ongoing research.

Of course, such technologies raise many security and privacy concerns. If not addressed properly, such concerns could become a major roadblock, preventing the development and broad use of implantable systems. Two contributions discuss this problem. "Security and Privacy for Implantable Medical Devices," by Daniel Halperin, Thomas S. Heydt-Benjamin, Kevin Fu, Tadayoshi Kohno, and William H. Maisel, presents an overview of security and privacy issues that arise when using implantable medical devices. The second contribution is an interview with Ari Juels, chief scientist and director of RSA Laboratories. Juels discusses future developments that he anticipates will address multiple aspects of security and privacy concerns in medical applications.

Also, because implantable systems are, by nature, inaccessible after installation, another important issue is low-power operation. Two articles focus on this problem. "A Cochlear-Implant Processor for Encoding Music and Lowering Stimulation Power," by Ji-Jon Sit and Rahul Sarpeshkar, discusses using analog rather than digital electronics for signal processing to save power in a cochlear implant. In "Piezoelectric Nanogenerators for Self-Powered Nanodevices," Zhong Lin Wang, Xudong Wang, Jinhui Song, Jin Liu, and Yifan Gao discuss piezoelectric nanowires that might one day help harvest energy for ultra-low-power implantable systems.

The issue also includes a Spotlight department on a pilot study that represents a first step toward implementing advanced treatment strategies using implantable electronics that optimize clinical outcomes by systematically capturing and analyzing data. "Processing Wearable Sensor Data to Optimize Deep-Brain Stimulation," by Shyamal Patel, Todd Hester, Richard Hughes, Nancy Huggins, Alice Flaherty, David Standaert, John Growdon, and Paolo Bonato, discusses how implantable systems can mitigate symptoms of Parkinson's disease. Adjusting and regulating stimulation pulses for deep-brain stimulation, a technique used to reduce Parkinson's symptoms, is a complex task that can benefit from wearable sensors and pattern recognition.

We're witnessing an important time in history. Technology is merging with the anatomy and physiology of humans to supplement or replace functions that the cardiovascular, nervous, muscular, endocrine, visual, and auditory systems normally provide. Numerous challenges exist, but we're rapidly closing the gap between bench research and clinical application of implantable systems. These systems have the potential to significantly improve the quality of life in individuals who would otherwise suffer from major impairments and functional limitations. We hope that the articles in this special issue provide a stimulating overview of this very exciting field.

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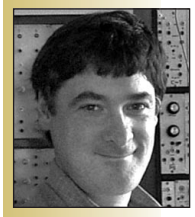

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