Introduction

Recent years witnessed an explosive growth in wearable technology. A wearable device is essentially a tiny computer with sensing, processing, storage and communications capabilities. May wearable devices also include interfaces and actuation capabilities that provide feedback to the user. The concept of a wearable device is not new, but the area is experiencing a rapid growth in popularity due to several factors that we try to explore below.

Historically, the concept of a wearable device goes back for centuries, with the pocket and wrist watches being the best know examples of a widely popular device that is still in use today. First watches designed to be worn appeared in the sixteenth century and were serving more as a decoration rather than a practical device for keeping time. These wearable mechanical devices evolved from rather cumbersome pieces worn as attachments to clothing or on a chain around the neck to a pocket and then to a wrist worn device. The evolution of the mechanical watch technology involved invention of self-winding watches, or early form of what today is known as energy harvesting. The technology also migrated from purely mechanical device to electromechanical and then to electronic devices that provide better accuracy and better functionality at a much lower cost. However, this evolution took almost 500 years. The pace of progress has increased dramatically in recent times and now the one of the oldest wearable technologies is being morphed with a relative newcomer that is less than 50 years old.

Handheld mobile phones are extremely popular descendants of mobile phone technology originally developed for use in vehicles. The handheld mobile phone began its history in the 1970s, with the first commercial services starting in the 1980s, and they took the world by storm. The capability of the new device to provide instant communication made the technology widely accepted and extremely successful. The co-evolution of the mobile phones and electronic technology lead to continuous miniaturization, making the mobile phone a truly wearable device found in billions of pockets on every single day. The merging of computer capabilities and instant communication created the modern generation of the smartphones that provide capabilities well beyond of those expected from a phone in its classical definition. These devices connect us to the world, organize our daily life, capture the memories though images and video, provide entertainment and serve in many other roles. Here is where the old meets the new in the emergence of "smart watches" that combine a century-old concept of a wrist worn device with the modern technological advances that pack the power of a smartphone in a watch form factor. The boundary between the devices is becoming increasingly blurry, with many people delegating time keeping to their phone or having phone functionality in their watches.

The acceptability of watches and mobile phones across different cultures, generations and societies demonstrates that wearable technology is a major part of our life and will be

becoming increasingly involved in every aspect. Wearable devices provide utility and convenience not available through any other means and extend our capabilities as humans. Wearable sensors are extremely popular as personal tracking devices that today are used primarily as monitoring devices, but the age of wearable is yet to come with multiple applications in personalized health, wellness/sports/fitness, rehabilitation, personal entertainment, social communications and lifestyle computing. Whether being able to tell time, connect to almost anyone almost anywhere, track one's exercise or monitor a patient on a hospital, wearable technology makes us more efficient by relying on its multiple capabilities.

Modern technology is the true enabler for the current and future generations of wearable devices. The roots of the rapid growth can be tracked to a few fundamental advances:

- Sensors: Advances in Micro-Elecro-Mechanical Systems (MEMS) and Nano technologies enable creation of miniature and inexpensive sensing solutions for a variety of electrical, mechanical, optical, chemical and other variables of interest that can be captured from or around the human body.
- Storage: The data captured by the sensors often need to be accumulated and stored for processing, especially in situations where a communication link may not be readily available. The recent advances in the solid state storage opens the door for collection of large datasets using wearable devices.
- Computation: Dramatic increase in the processing capabilities, reduction in power consumption and decrease in size of embedded processors facilitates real-time signal processing and pattern recognition in battery-powered wearable devices. The techniques of machine learning and computational intelligence enable a new, never before seen capability to provide real-time pattern recognition in the sensor data which may identify events of interest (for example, an elderly person experiencing a fall) and acting upon or providing real-time feedback on such events.
- Communication: Rapidly evolving wireless communication techniques permit instantaneous information delivery virtually anywhere in world and processing of the data in the "cloud". The data from a wearable device can be almost instantaneously delivered anywhere in the world. The communications channels can carry sensor data or messages and alerts generated by the device.
- Interface: Modern interfaces go well beyond LEDs and flatscreen technology, delivering results of the sensor data processing in a compelling, easy to understand manner accessible by an individual without advanced technological knowledge though tactile, audible, visual or haptic interfaces.

These fundamental advances are supplemented by complementary technologies that enable operation of body-worn devices: ongoing miniaturization of electronic devices, advances in materials science leading to creation of smart textiles, and flexible electronics, advances in battery technology, energy harvesting and so on.

Overall, wearable technology epitomizes the interaction of humans and technology and as such, covers a very broad area that requires a mixture of expertise quite often hidden in a disjointed array of academic publications in fields of science and technology that normally may not interact with each other. How many electrical engineers took classes in knitting technology? How many behavioral scientists studied sensors? The list can

continue. This book attempts to present a holistic view of the various aspects of wearable technology, originating from different fields of study. While by no means all-inclusive, the book is organized into several sections that act as an umbrella over a few key aspects of wearable technology. The chapters in each section are written by the world's best experts that present their unique view on the field.

Section 1, "Wearable design issues and user interfaces" provides an introduction to the world of wearables, talks about key applications that drive development of wearable systems, discusses issues of social acceptance, practicality and convenience and provides an example of a novel user interface.

Section 2, "Fundamentals of sensors in wearable devices" focuses on various aspects of sensor technology, ranging from physiological monitoring, inertial, bio and chemical sensors, to optical and heat flow sensors. The sensor technologies described in this section provide an overview of the fundamental sensor modalities used in wearable technology.

Section 3, "Smart fabrics and flexible electronics" describes two key techniques used in production of smart textiles: knitting and weaving, and also provides several examples of practical applications of smart textile technology. The final chapter of this section portrays in depth the emerging field of flexible electronics technology that finds one its primary applications in the production of smart textiles.

Section 4, "Energy harvesting from human body" looks at the possible ways to perform battery charging or battery-free operation from the energy generated by the human body. This section discusses a variety of techniques and issues associated with energy harvesting.

Section 5, "Analog and digital signal processing, pattern recognition and data analysis" looks at techniques for processing of sensor data. Being severely energy-constrained, wearable sensors need to rely on a combination of energy-efficient analog and digital signal processing and pattern recognition techniques. Wearable sensors may also generate massive amounts of data that can be viewed as a part of the "Big Data" challenge and need advanced algorithms for data mining. This section describes techniques for efficient on-body processing as well as off-line mining of sensor data.

Section 6, "On-body communications and body area networks" deals with issues of communication around or through the human body. The chapters in this section describe design issues in wireless networks, channel propagation models, security and trust in wireless communications, and localization of sensors.

Section 7, "Applications" covers several examples of wearable sensor technology used in less conventional applications such as use of wearables as assistive technology for wheelchair-bound individuals, use of sensors worn inside of the body for gastric disease monitoring, and detection and characterization of diet, food intake and ingestive behavior in community-dwelling individuals.

In summary, the book describes the fundamentals, practical implementation and applications of wearable technology. Written by the leading experts in the field, the book also provides insights into future directions of the technology. We hope that this volume will be useful for researchers in academy and industry, students and practitioners who would like to obtain a comprehensive overview of the fascinating world of wearables.