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Vivian Genaro Motti

Wearable Interaction

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This book is dedicated to my grandparents, Antônio Genaro (in memorian) and Encarnação Flores Genaro, my guiding stars and fortress.

Foreword by Massimo Zancanaro

Wearable devices are at the same time a huge market potential and a lively research topic. Sales of wristbands, smartwatches, and ear-worn devices are growing steadily in the last few years and an even stronger growth has been foreseen for the near future [3]. Research is rampant in different areas including core technical challenges such as standardization [8] or processing [5] as well as in specific application fields such as precision medicine [2], sport [4], or operation in difficult environments [6], just to name a few literature surveys recently published.

Nevertheless, there is a huge gap in understanding and designing the user experience. First because, despite their apparent minimalism, wearable devices may be complex to use, if not properly designed and understood by the users [1]. Second because, even in the fields where they have longer been applied such as sport, for example, innovation seems largely focused on technical aspects rather than on how people appropriate and use wearable devices in the long term as well as how these devices can eventually change the experience of physical activity [4].

Therefore, wearable interaction, with its emphasis on interface and interaction aspects, is timely. Vivian Genaro Motti brings in this book her personal research experience together with a detailed analysis of the extant literature to provide a unifying picture on the knowledge on interface solutions for wearable technologies.

Wearable computing is not a new research field, as the first chapter dutifully illustrates, but it is sparse and, in many respects, incomplete. An overview about wearable computers was long needed starting by a reflection on basic definitions and fundamental concepts up to discussing more advanced aspects like the tension between universal use and adaptation.

Since the market is becoming more mature, the competition is going to move from the novelty effect to usefulness and usability. In this respect, the extensive list of design principles and patterns, together with guidelines and recommendations to design and evaluate wearable solutions, offers an important contribution as didactic material to train a new generation of professionals in this area.

Wearable Interaction is a fascinating book offering a comprehensive view on a lively research field and at the same time an interesting reference for designers and professionals.

July 2019

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Foreword by Gerrit Meixner

When I got the invitation from Vivian Genaro Motti, I was happy to support her, encouraging her book project about wearable interaction. Concerning myself, I am professor for Human–Computer Interaction and working in the area for 15 years now. I know Vivian since she was a Ph.D. student at UCL in Belgium.

Writing a book about such an ongoing topic like wearable computing and having a focus on the interaction part of wearable computer is quite ambitious, because quick innovations change this area rapidly.

The book consists of five chapters beginning with an introduction to wearable computers. The introduction is typically the most interesting part for me—here I decide if I go on reading the rest of the book. In the case of this book, I very much like the historical background of the technology. I have several lectures at my university talking only about the historical background, how technology has evolved over the last decades and how it changed human's life. This is very important, because you get to know why things failed in early times and why they became successful later. The last part of the introduction concerning application domains of wearable computers gives a nice overview of use scenarios in our real world.

The second chapter is about design considerations. A wearable computer is a (mostly tiny) complex electronic product you wear on your body. Developing it is like developing a new Personal Computer—with a dozen problems more (I can tell you… we once had a project developing a wearable computer—a ring—for a big German company). Therefore, please, put the user in the center of your development and be as close as possible toward ISO 9241-210. Your customer and user will be very thankful.

The third chapter is about wearable interaction. There are so many ways of interacting with a wearable computer and this chapter helps you thinking about the right interaction modality.

The fourth chapter is about design guidelines and evaluation. By using (good) guidelines, you ensure that you do not do the same mistakes as many people did before you. Evaluating your designs, sketches, (physical) prototypes is indispensable for developing your new great gadget in a user-centered way. The fifth and last

chapter is about future trends in wearable computing. It discusses several directions research will go or may go.

For me, the future of wearable interaction is very promising. In some years, humans will be highly extended with wearable computers on their bodies—ranging from smart eyewear to smart shoes.

July 2019

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Preface

Wearable Interaction provides readers with a comprehensive view about wearable computing, focusing on the design of the user interface, input entries, and output responses across form factors and application domains.

This book originates from the author's idea to unify the knowledge on interface solutions for wearable technologies. The intended audience includes designers and developers, from academia or industry, interested in learning about multimodal interfaces for wearables that are effective for end users to interact with. This book presents and discusses diverse interaction modalities, including approaches for input entry and output responses, with feedback that leverages on audio, graphic, haptic, and tactile solutions. The examples presented in the book were extracted from scientific literature but include commercial devices as well. The devices presented cut across multiple form factors, ranging from head-mounted displays to wrist-worn devices.

Wearable interaction provides an overview about wearable computers, focusing on human factors, user experience, and interaction design. The book is structured in five chapters.

In brief, Chap. 1 provides basic definitions and fundamental concepts in the domain, including a historic view and multiple examples of wearable technologies, illustrated through different form factors, including wrist-worn wearables, head-mounted displays, and smart garments. Eight application domains are discussed, including healthcare, education, and user interaction. Chapter 2 discusses the design considerations necessary to create interactive solutions for wearables, describing human factors, technological constraints, and universal design concerning customization choices for input entry and output responses. Chapter 3 focuses on the design of multimodal user interfaces and interactive solutions for diverse wearables. The examples of designs presented consider multiple modalities for input entry and output responses and multiple form factors as well. References from scientific literature and commercial examples are combined for illustration. This chapter emphasizes the different contexts of use where the wearable interaction

takes place, discussing how different contextual factors impact the user experience with wearable computers. Chapter 4 provides a theoretical foundation to facilitate the design process, including guidelines, principles, and interaction paradigms that support the development life cycle and the evaluation of interactive applications for wearable technologies. To identify and discuss the main benefits and drawbacks involved in wearable interaction, several quality factors are described. Chapter 5 discusses future trends and concerns in the domain, illustrating examples of seamless solutions that are embedded or projected on the users' bodies. It also provides a critical reflection on the design of interactive solutions according to the design considerations, privacy concerns, and quality criteria described.

Each chapter of wearable interaction is summarized as follows:

Chapter 1 In the Introduction to wearable computers, the readers have an overview about the history of wearable computers, including different form factors, sensors, and actuators. The versatility of wearable computers to support everyday activities is emphasized, explaining multiple application domains that benefit from wearable solutions.

Chapter 2 In design considerations, a conceptual view of wearable computers is defined, including different placements on the user body, and multiple factors involved in the interaction design. This chapter emphasizes the constraints of the devices and the heterogeneous contexts of use where wearables are used. It also explains why microinteractions are important in such dynamic contexts, highlighting the diversity of users and considerations concerning ergonomic aspects. Lastly, the main design challenges are discussed, including trade-offs when universal design and customization must be considered to ensure acceptability among users.

Chapter 3 In wearable interaction, a number of interactive solutions for input and output are presented, as well as interaction paradigms and multimodal interfaces across form factors. The user interaction is illustrated for wrist-worn devices and head-mounted devices. Alternative form factors, such as back-mounted devices and chest-mounted devices, are also discussed.

Chapter 4 In design guidelines and evaluation, the readers have access to an extensive list of design principles and patterns, guidelines, and recommendations that must be taken into account when stakeholders are creating or evaluating wearable solutions. The contents guide a design process by providing a comprehensive list of principles that must be employed by stakeholders when developing wearables and also inform the evaluation phases by providing multiple methods for assessing and improving wearable technologies.

Chapter 5 Future trends in wearable computing conclude the book by presenting a critical view of novel interfaces, focusing on the miniaturization of devices as well as on-body interfaces. This chapter discusses electronic tattoos and implanted devices that are seamlessly connected to the users' body. It concludes with opportunities to further develop wearables.

Fairfax, USA
January 2019

Vivian Genaro Motti

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About the Author

Vivian Genaro Motti is an Assistant Professor on Human–Computer Interaction in the Department of Information Sciences and Technology at George Mason University (GMU) where she leads the Human–Centric Design Lab (HCD Lab). Her research focuses on Human–Computer Interaction, Ubiquitous Computing, Wearable Health, and Usable Privacy. Before joining GMU, she was a Postdoctoral Research Fellow and a Research Assistant Professor in the Human-Centered Computing division at the School of Computing in Clemson University. During her postdoc, she contributed to the NSF-funded Amulet project, investigating human factors, usability, and privacy of wearable devices for health care.

Dr. Motti received her Ph.D. from the Université Catholique de Louvain (Louvain la Neuve, Belgium) in 2013. During her Ph.D., she investigated the multidimensional adaptation of user interfaces to the context of use. She earned a B.Sc. and a Masters degree from University of São Paulo. In her Master's thesis, she investigated usability issues in a ubiquitous computing environment for distributed meetings (DiGaE) in learning environments. The ultimate goal of her research is to bridge the gap between what users need and what technology actually provides them.

Acronyms

2D	Two dimensional
3D	Three dimensional
ACM	Association for Computing Machinery
ANT+	Adaptive Network Topology
AR	Augmented Reality
BAN	Body-Area Network
BCI	Brain–Computer Interface
BLE	Bluetooth Low Energy
BP	Blood Pressure
BVP	Blood Volume Pulse
COTS	Commercial off-the-shelf
CRS	Comfort Rate Scale
DIY	Do-it-yourself
DOF	Degree of Freedom
ECG	Electrocardiogram
EDA	Electrodermal Activity
EEG	Electroencephalogram
EMG	Electromyogram
EOG	Electrooculogram
FRAM	Ferroelectric Random Access Memory
GB	Gigabyte
GDPR	General Data Protection Regulation
GMU	George Mason University
GSR	Galvanic Skin Response
GUI	Graphic User Interface
HMD	Head-Mounted Devices
Hz	Hertz
I/O	Input and Output
ICU	Intensive Care Unit
IEEE	Institute of Electrical and Electronic Engineers

IR	Infrared
LED	Light-Emitting Diode
MHz	Mega-hertz
mm	Millimeters
NDD	Neurodevelopmental Disorders
NFC	Near-Field Communication
OS	Operating System
PAN	Personal Area Network
PC	Personal Computer
pH	Potential of Hydrogen
PPG	Photoplethysmograph
REBA	Rapid Entire Body Assessment
RFID	Radio-Frequency Identification
RTC	Real-time clock
SD	Secure Digital
SMS	Short Message Service
UI	User Interface
USB	Universal Serial Bus
VR	Virtual Reality
WC	Wearable Computing
WIMP	Window icon menu pointer
WIVR	Wearable Immersive Virtual Reality
WWW	Wrist-Worn Wearables