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Editors

Brain-Computer Interfaces

Applying our Minds to Human-Computer Interaction

Springer

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Preface

Human-Computer Interaction (HCI) research used to be about the ergonomics of interfaces and, interfaces used to consist of a keyboard, a mouse and whatever could be displayed on the screen of a monitor, that is, the graphical user interface. Nowadays, when we talk about Human-Computer Interaction research, we are talking about multimodal interaction in environments where we research natural human behavior characteristics in general, rather than looking at keyboard and mouse interaction. The environments we live in support us in our activities. Sensor-equipped environments know about us, our activities, our preferences, and about our interactions in the past. This knowledge is obtained from our interaction behavior, behavior that can be observed and interpreted using knowledge that becomes available and that can be fused from cameras, microphones, and position sensors. This allows the environment to not only be reactive, but also proactive, anticipating the user's activities, needs and preferences.

Less traditional sensors are now being introduced in the Human-Computer Interaction field. The aim is to gather as much information as possible from the human interaction partner and the context, including the interaction history, that can be sensed, interpreted, and stored. This information makes it possible for the environment to improve its performance when supporting its users or inhabitants in their daily activities. These sensors detect our activities, whether we move and how we move and they can be embedded in our clothes and in devices we carry with us. In the past, physiological sensors have been used to evaluate user interfaces. How does the user experience a particular user interface? What can we learn from information about heart rate, blood pressure and skin conductivity about how a user experiences a particular interface? Such information can help in improving the design of an interface. At present we see the introduction of these physiological sensors in devices we carry with us or that are embedded in devices that allow explicit control of computer or computer controlled environments. Hence, this information can be used 'on-line', that is, to improve the real-time interaction, rather than 'off-line', that is, to improve the quality of the interface. This information gives insight in the user's affective and cognitive state and it helps us to understand the utterances and activities of the user. It can be used to provide appropriate feedback or to adapt the interface to the user.

Now we see the introduction of sensors that provide us with information that comes directly from the human brain. As in the case of the physiological sensors mentioned above, information from these neuro-physiological sensors can be used to provide more context that helps us to interpret a user's activities and desires. In addition, brain activity can be controlled by the user and it can be used to control an application. Hence, a user can decide to use his or her brain activity to issue commands. One example is motor imagery, where the user imagines a certain movement in order to, for example, navigate in a virtual or physical environment. On the other hand, an environment can attempt to issue signals from which it can become clear, by looking at the initiated brain activity, what the user is interested in or wants to achieve.

The advances in cognitive neuroscience and brain imaging technologies provide us with the increasing ability to interface directly with activity in the brain. Researchers have begun to use these technologies to build brain-computer interfaces. Originally, these interfaces were meant to allow patients with severe motor disabilities to communicate and to control devices by thought alone. Removing the need for motor movements in computer interfaces is challenging and rewarding, but there is also the potential of brain sensing technologies as input mechanisms that give access to extremely rich information about the state of the user. Having access to this information is valuable to Human-Computer Interaction researchers and opens up at least three distinct areas of research: controlling computers by using thought alone or as a complementary input modality, evaluating systems and interfaces, and building adaptive user interfaces.

Specifically, this book aims to identify and discuss

- Brain-computer interface applications for users with permanent and situational physical disabilities, as well as for able-bodied users; this includes application in domains such as traditional communication and productivity tasks, as well as in games and entertainment computing;
- Sensing technologies and data processing techniques that apply well to the suite of applications in which HCI researchers are interested;
- Techniques for integrating brain activity, whether induced by thought or by performing a task, in the palette of input modalities for (multimodal) Human-Computer Interaction

The Human-Computer Interaction field has matured much in the last several decades. It is now firmly rooted as a field that connects more traditional fields such as computer science, design, and psychology in such a way as to allow us to leverage and synthesize work in these spaces to build technologies that augment our lives in some way. The field has also built up well-defined methodologies for repeating this work across a series of disciplines. Simultaneously, neuroscience continues to advance sufficiently fast and brain-computer interfaces are starting to gain enough traction so that we believe it is a field ripe for collaboration with others such as HCI. In fact, we argue that the specific properties of the two fields make them extremely well suited to cross-fertilization, and that is the intent of this book. That said, we hope that the specific way we have crafted this book will also provide brain-computer interface researchers with the appropriate background to engage with HCI researchers in their work.

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Acronyms

AAT	Alpha Attenuation Test
ACT	Anatomically Correct Testbed
A-LOC	Almost Loss of Consciousness
ALS	Amyotrophic Lateral Sclerosis
AP	Average Precision
aPFC	Anterior PreFrontal Cortex
BCI	Brain-Computer Interaction
BIRT	Brain-Interface Run-Time
BMI	Brain-Machine Interaction
CAUS	Covert Aspects of User State
CBF	Cerebral Blood Flow
CI	Control Interface
CNV	Contingent Negative Variation
CSP	Common Spatial Patterns
DOF	Degrees of Freedom
ECG	ElectroCardioGram
ECoG	ElectroCorticoGraphic
EEG	ElectroEncephaloGraphy
EMG	ElectroMyoGram
EOG	ElectroOculoGram
ERD	Event Related Desynchronization
ERN	Error Related Negativity
ERP	Event Related Potentials
ERS	Event-Related Synchronization
FES	Functional Electrical Stimulation
FFT	Fast Fourier Transform
fMRI	functional Magnetic Resonance Imaging
FN	False Negative rate
fNIR	functional Near-InfraRed Sensing
fNIRS	functional Near-InfraRed Spectroscopy
FP	False Positive rate

GEQ	Game Experience Questionnaire
G-LOC	Gravity-induced Loss of Consciousness
GOMS	Goals, Operators, Methods and Selection rules
GUI	Graphical User Interface
HCI	Human-Computer Interaction
HSWM	High Spatial Working Memory
ICA	Independent Component Analysis
ITR	Information Transfer Rate
LDA	Linear Discriminant Analysis
LRP	Lateralized Readiness Potential
LSWM	Low Spatial Working Memory
MEG	MagnetoEncephaloGraphy
MMN	MisMatch Negativity
NIR	Near-InfraRed
NPC	Non-Player Character
OOI	Objects of Interest
PCT	Perceptual Control Theory
PET	Positron Emission Tomography
PFC	PreFrontal Cortex
PSoC	Programmable System-on-a-Chip
QDA	Quadratic Discriminant Analysis
RJB	Right Justified Box
RP	Readiness Potential
RSVP	Rapid Serial Visual Presentation
SCP	Slow Cortical Potential
SMR	SensoriMotor Rhythm
SPECT	Single Photon Emission Computed Tomography
SSEP	Somato Sensory Evoked Potential
SSVEP	Steady-State Visual Evoked Potentials
SWDA	Stepwise Discriminant Analysis
TLS	Total Locked-in Syndrome
TP	True Positive rate
TTD	Thought Translation Device
TTI	Target to Target Interval
UI	User Interface
VEP	Visually Evoked Potential
WM	Working Memory