Prolog to the Section on Neurotechnological Systems: The Brain–Computer Interface

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As the proliferation of technology dramatically infiltrates all aspects of social life, engineering will continue to intertwine the human brain with technology, thus forming integrated neurotechnological systems. Major forerunners of such a conception are brain–computer interfaces (BCIs), which are based on a direct communication pathway between the human brain and an external device. First developed in the 1970s, BCIs have been largely focused on improving the quality of life of particular clinical populations and include, for example, advanced communications with locked-in patients and the direct control of prostheses and wheelchairs. Over the past five years there has been an explosion of research and development into technologies underlying the use of online brain–signal processing to influence human interactions with computers, their environment, and even other humans, i.e., BCI technologies, which has even led to the commercialization of the first brain-based toys. Over the next decades, BCI technology will expand beyond integration in medical and laboratory settings and into everyday life.

This special section on neurotechnological systems focuses on current and potential brain–computer interface (BCI) technologies and research enabled by recent advances in wearable, mobile biosensors and data acquisition as well as advances in neuroscience and computing for brain imaging and related fields.

In this section of the Centennial Special Issue, we focus on current and potential BCI technologies and research enabled by recent advances in wearable, mobile biosensors and data acquisition; neuroscience; computational and analytical approaches; and computing for brain imaging in real-world environments. In the first paper, Liao *et al.* discuss barriers to taking brain imaging systems out of laboratory and clinical settings and into everyday environments, and highlight current and future approaches to address those barriers. This paper focuses on recent and projected advances of a wide range of sensor and acquisition neurotechnologies enabling online brain–signal processing in everyday, real-life environments. In the second paper, Makeig *et al.* discuss the challenges associated with building robust and useful BCI models from accumulated biological knowledge and available data, and the technical problems associated with incorporating multimodal physiological, behavioral, and contextual data that may become ubiquitous in the future. This paper focuses on recent advances and current trends in signal processing of electroencephalography (EEG) data and future approaches to processing EEG in combination with multimodal sources of data. One of the primary benefits of the neurotechnologies discussed in the first two papers is that they are envisioned to enable researchers to experiment using naturalistic tasks and in real-world environments to produce a much deeper and perhaps very different understanding of the link between behavior and biology; an understanding which may dramatically influence BCI technologies as well as the broader neuroscience community. In the third paper, Lance *et al.* discuss the potential of using online brain–signal processing to enhance human–computer interactions and the barriers to realizing this potential. This paper discusses past and current BCI applications and proposes future BCI technologies that will make significant expansion into training, education, entertainment, rehabilitation, and human–system performance domains. These technologies include novel user-acceptable interfaces to monitor brain function and human behaviors in real-world environments.

The vast growth in neuroscience research over the past several decades presents a remarkable opportunity to synthesize and leverage this knowledge base for improving

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human–system technologies. In other words, neurosciences and neurotechnologies offer an opportunity to revolutionize human–system performance by integrating modern neuroscience with human factors, cognitive science, computer science, materiel development, and engineering to enhance our understanding of human function in complex real-world settings and develop novel and effective systems design. With increasing technology development, in many ways the world is becoming more dynamic and complex. It now becomes critical to design and develop flexible and adaptive systems that integrate with, and capitalize on humans' abilities and limitations. ■

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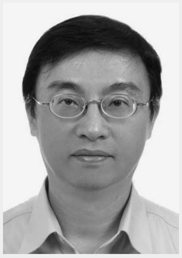

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