Noninvasive BCIs: Multiway Signal-Processing Array Decompositions

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In addition to helping better understand how the human brain works, the brain-computer interface neuroscience paradigm allows researchers to develop a new class of bioengineering control devices and robots, offering promise for rehabilitation and other medical applications as well as exploring possibilities for advanced human-computer interfaces.

Brain computer interfaces (BCIs) are systems that use electric, magnetic, or hemodynamic brain signals to control external devices such as computers, switches, wheelchairs, or neuroprostheses. While BCI research endeavors to create new communication channels for severely handicapped people using their brain signals, recent efforts also have been focused on developing potential applications in rehabilitation, multimedia communication, virtual reality, and entertainment/relaxation.[1-14]

The three major components of BCIs are:[2]

- ways of measuring neural signals from the human brain,
- methods and algorithms for decoding brain states/intentions from these signals, and
- methodology and algorithms for mapping the decoded brain activity to intended behavior or action.

Several existing brain monitoring technologies have been tested in BCI research for acquiring data—for example, electroencephalography (EEG), magnetoencephalography (MEG), functional magnetic resonance imaging (fMRI), and near infrared spectroscopy (NIRS). However, because MEG, fMRI, and NIRS are expensive or bulky, and because fMRI and NIRS present longtime constants in that they do not measure neural activity directly—relying instead on the hemodynamic coupling between neural activity and regional changes in blood flow—they cannot be deployed as ambulatory or portable BCI systems. As a result, the majority of promising BCI systems to date exploit EEG signals.[1-9]

Raw brain data is rarely of substantial benefit, as its real value depends on data quality and on signal-processing, machine-learning, and data-mining tools to analyze the data and extract useful information. To attain high-quality brain data and, thus, a reliable BCI system, we first need to create the stimulus conditions or mental task setting that will generate maximally measurable and classifiable brain states. Next, we need to optimize the measurement procedure and develop real-time signal-processing algorithms that decode and interpret the resulting brain signals. Finally, we must integrate these features into an interface that has optimal functionality and usability.[2-6]

WHY BRAIN-COMPUTER INTERFACES?

There are several reasons why BCI is an important and active research area:

- BCI is a new neuroscience paradigm that may help us better understand how the human brain works

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