Chapter 80
Brain-Machine Interface Using Brain Surface Electrodes:
Real-Time Robotic Control and a Fully Implantable Wireless System

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ABSTRACT

The brain-machine interface (BMI) enables us to control machines and to communicate with others, not with the use of input devices, but through the direct use of brain signals. This chapter describes the integrative approach the authors used to develop a BMI system with brain surface electrodes for real-time robotic arm control in severely disabled people, such as amyotrophic lateral sclerosis patients. This integrative BMI approach includes effective brain signal recording, accurate neural decoding, robust robotic control, a wireless and fully implantable device, and a noninvasive evaluation of surgical indications.

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INTRODUCTION

The brain-machine interface (BMI) is a man-machine interface that enables us to control machines and to communicate with others not with the use of input devices, but through the direct use of brain signals alone (Figure 1). Several diseases and conditions can lead to the loss of muscular control without a disruption in patients' brain function, including amyotrophic lateral sclerosis (ALS), brainstem stroke, spinal cord injury, and muscular dystrophy, among others. BMI technology offers these patients greater independence and a higher quality of life by enabling the control of external devices to communicate with others and the ability to manipulate their environment at will (Wolpaw, Birbaumer, McFarland, Pfurtscheller, & Vaughan, 2002).

There are two types of BMI: invasive BMI and noninvasive BMI. Invasive BMI requires surgical procedures and measures the brain signals from intracranial electrodes (needle electrodes or brain surface electrodes), whereas noninvasive BMI measures brain signals noninvasively from outside of the body using scalp electrodes, and so forth. To achieve a higher performance and a higher level of usefulness, we employed invasive BMI techniques, which involve the implantation of devices. For use in a practical situation, invasive BMI requires an organic integration of the following medical and engineering technologies:

1. Neural recording with high spatiotemporal resolution.
2. High-speed data transfer and processing.
3. Optimal extraction of appropriate neurophysiological features.
4. Accurate neural decoding.
5. Robust control of external devices such as robotic arms and electric wheelchairs.
6. Downsizing, integration, and implantation of electronic devices, and the use of wireless technology.
7. Noninvasive pre-surgical evaluations for appropriate surgical indications.
8. On-target survey and analysis of patient needs.
9. Addressing of neuroethical issues.

In this chapter, we describe the development of our invasive BMI system using brain surface electrodes.

NEURAL DECODING AND REAL-TIME ROBOTIC CONTROL USING ELECTROCORTICOGRAMS

Clinical Studies Using Electrocorticograms Recorded from Brain Surface Electrodes

In the process of providing neurosurgical treatments for specific groups of patients, we sometimes record brain signals (electrocorticograms: ECoGs) or electrically stimulate the brain using

Figure 1. A conceptual diagram of the brain machine interface