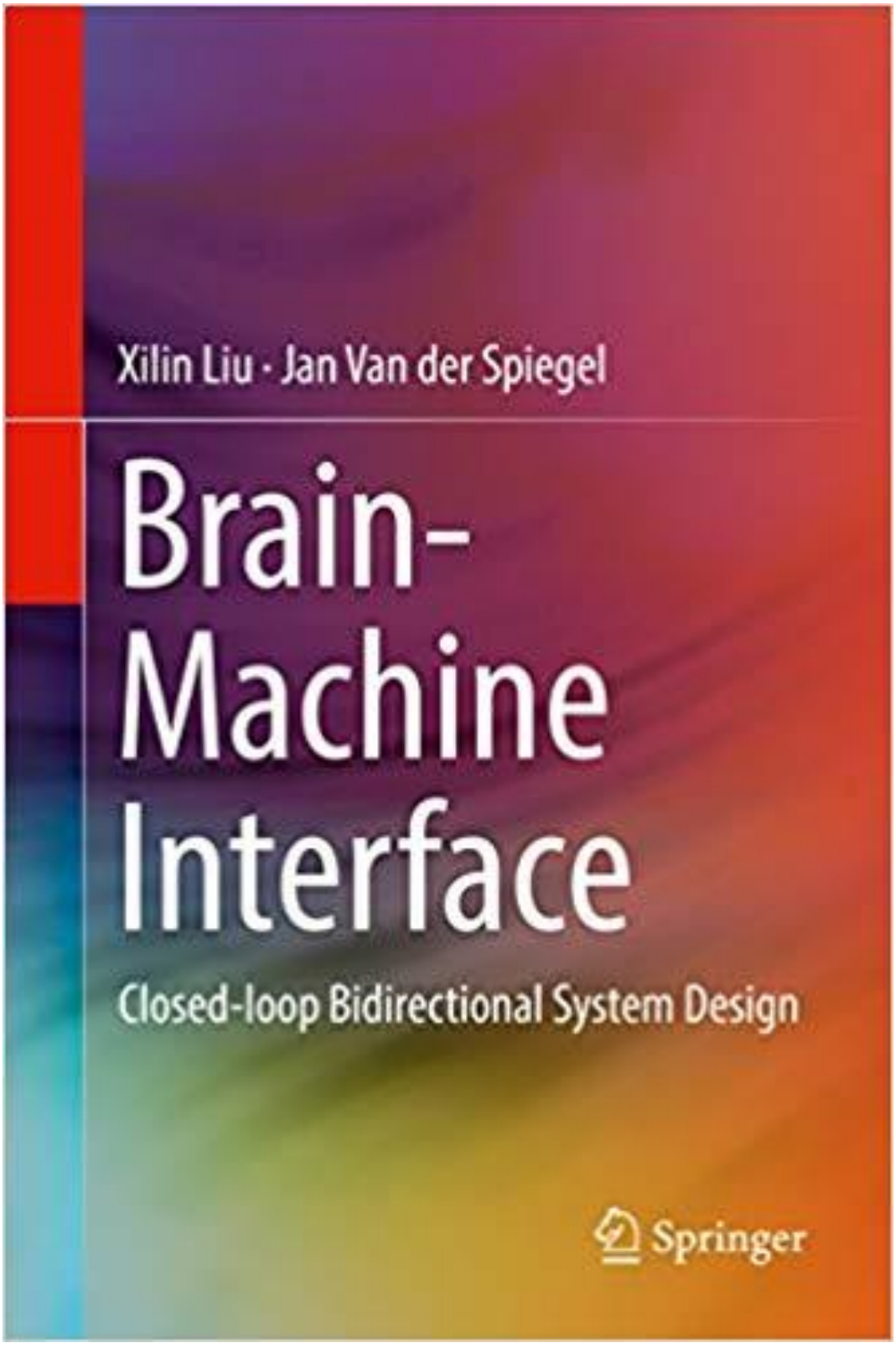
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Brain-Machine Interface
Closed-loop Bidirectional System Design
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Chapter 1
Introduction

1.1 Background and Motivation

Since the dawn of human civilization, people have started the attempts to study the brain, with the hope that it will give us answers to fundamental questions like who we are, where is the consciousness from. However, even with the science and technology advancements nowadays, many mechanisms of brain functions remain unclear. There are about a hundred billion neurons in a human brain [1], approximating the number of stars estimated in our galaxy [2]. Each neuron establishes connections with seven thousand other neurons on average, forming a massive neural network. Interestingly, neurons represent the information in terms of electrical signals by distributing ions with different charges [3]. This gives electrical engineers a unique opportunity to design artificial devices for collecting the neural signal, and more importantly, generating electrical signals imitating the neural signal. The direct communication pathway between the brain and the external world is named brain–machine interface (BMI), brain–computer interface (BCI) or neural interface [4].

The first BMI experiment was conducted by Jacques Vidal from University of California, Los Angeles in 1973 [5], for an observation and detection of brain events in electroencephalogram (EEG). The first intracortical BMI was built by Phillip Kennedy from Georgia Institute of Technology in 1987 [6]. The first demonstration of controlling a physical object using EEG signal was reported by S. Bozinovski in 1988 [7]. In 1999, Yang Dan and researchers at University of California, Berkeley decoded neuronal firings to reproduce images seen by cats [8]. The same year, John K. Chapin and researchers from MCP Hahnemann School of Medicine and Duke University demonstrated the first direct control of a robotic manipulator by decoding an assembly of cortical neurons [9]. In 2000, Miguel A. Nicolelis and his colleagues from Duke University developed BCIs that decoded brain activity in monkeys and used the devices to reproduce monkey movements in robotic arms [10]. The same year, Gerwin Schalk from the Wadsworth Center of New

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