Machine Learning and Wireless Communications

How can machine learning help the design of future communication networks, and how can future networks meet the demands of emerging machine learning applications? Discover the interactions between two of the most transformative and impactful technologies of our age in this comprehensive book.

First, learn how modern machine learning techniques, such as deep neural networks, can transform how we design and optimize future communication networks. Accessible introductions to concepts and tools are accompanied by numerous real-world examples, showing you how these techniques can be used to tackle longstanding problems. Next, explore the design of wireless networks as platforms for machine learning applications. An overview of modern machine learning techniques and communication protocols will help you to understand the challenges, while new methods and design approaches will be presented to handle wireless channel impairments such as noise and interference, to meet the demands of emerging machine learning applications at the wireless edge.

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To our families.

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Preface

Machine learning (ML) and wireless communications are two of the most rapidly advancing technologies of our time. The main premise of ML is to enable computers to learn and perform certain tasks without being explicitly programmed to do so. This is achieved by training algorithms on data available for the task to be accomplished. Although the basic ideas and ambitions of ML go back to the 1950s, there has been a recent surge in interest and applications in this area, fueled by the availability of increasingly powerful computers, large amounts of data, and developments in new learning algorithms as well as their theoretical underpinnings. At the same time, wireless communication has evolved, through advances in both theory and supporting technologies, to encompass a variety of application areas, from high-performance data transmission tasks such as media distribution to the massive deployment of end-devices to enable Internet of Things (IoT) tasks such as sensing, inference, and control.

We are now witnessing the confluence of these two fields, with two primary aspects to this connection. One is the application of ML techniques to the optimization of wireless networks. This is a natural use of ML, as wireless networks involve many inferential and control tasks, which often must operate under dynamic or uncertain conditions, and create many examplars for learning because data transmissions take place at very high rates. The other aspect of this connection is the use of wireless networks as ML platforms. This again is a natural application of emerging wireless networks, such as those supporting IoT applications, because they involve sensing, inference, and control and provide edge devices with considerable processing power. Learning at the network edge has advantages in terms of latency and privacy, and it capitalizes on the fact that many learning tasks, such as those supporting automated driving, are locality specific.

To realize the promise of these opportunities, significant research in many dimensions is needed. Important issues include the adaptation of existing ML techniques to wireless system design and the design and development of new techniques that can meet the constraints and requirements of communication networks, including the capability to implement at least some of these techniques in low-power chips that can be used in mobile devices, as well as developing fundamental analytical techniques and bounds on the performance of distributed ML algorithms operating within the constraints of wireless connectivity. This book focuses on these research issues through a series of 18 chapters written by experts in the field, beginning with an introductory chapter providing a brief general overview of ML methodology. By presenting a

systematic overview of the most promising aspects of the connection between ML in wireless networks, this book provides an entry point and a comprehensive overview of the state of the art for researchers in academia and industry who are interested in learning and contributing to this growing field.

This book is the culmination of the efforts of many people, including the chapter authors and the editorial and production staff at Cambridge University Press. We wish to express our deep gratitude for their contributions.