Compressive Sensing for Wireless Networks

Compressive sensing is a new signal-processing paradigm that aims to encode sparse signals by using far lower sampling rates than those in the traditional Nyquist approach. It helps acquire, store, fuse and process large data sets efficiently and accurately. This method, which links data acquisition, compression, dimensionality reduction, and optimization, has attracted significant attention from researchers and engineers in various areas. This comprehensive reference develops a unified view on how to incorporate efficiently the idea of compressive sensing over assorted wireless network scenarios, interweaving concepts from signal processing, optimization, information theory, communications, and networking to address the issues in question from an engineering perspective. It enables students, researchers, and communications engineers to develop a working knowledge of compressive sensing, including background on the basics of compressive sensing theory, an understanding of its benefits and limitations, and the skills needed to take advantage of compressive sensing in wireless networks.

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For the people I met in the Barneo ice camp, North Pole, who showed me the bravery to conquer any difficulty, which encouraged me to finish this challenging book **Zhu Han**

To my wife, Min Duan, and my son, Siyi Li **Husheng Li**

To those who advocate for intellectual honesty and defend academic integrity **Wotao Yin**

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Preface

Over the past few decades, wireless communications and networking have witnessed an unprecedented growth, and have become pervasive much sooner than anyone could have predicted. For example, cellular wireless networks are expected to become the dominant and ubiquitous telecommunication means in the next few decades. The widespread success of cellular and WLAN systems prompts the development of advanced wireless systems to provide access to information services beyond voice such as telecommuting, video conferencing, interactive media, real-time internet gaming, and so on, anytime and anywhere. The enormous potential demands for these wireless services require a careful design of the future networks. Many technical challenges remain to be addressed such as limited resources, adverse natures of wireless channels, interference, etc.

Today, with the increasing demand of higher resolution and increasing number of modalities, the traditional wireless signal processing hardware and software are facing significant challenges since the Nyquist rate, which is part of the dogma for signal acquisition and processing, has become too high in many wireless applications. How to acquire, store, fuse, and process these data efficiently becomes a critical problem. The most current solution to this problem is to compress after sensing densely. However, this oversampling-then-discarding procedure wastes time, energy, and/or other precious resources.

A new paradigm of signal acquisition and processing, named compressive sensing (CS), has emerged since 2004. Starting with the publication of "Compressed sensing" by D. Donoho, and a few seminal works by E. J. Candès, J. Romberg, and T. Tao, the CS theory, which integrates data acquisition, compression, dimensionality reduction, and optimization, has attracted lots of research attention. The CS theory consists of three key components: signal sparsity, incoherent sensing, and signal recovery. It claims that, as long as the signal to be measured is sparse or can become sparse under a certain transform or dictionary, the information in the signal can be encoded in a small number of incoherent measurements, and the signal can be faithfully recovered by tractable computation.

Since CS is so new a tool bearing a large number of potential applications in engineering, there is not yet a published book for the engineers. However, the applications of CS in wireless communication are very important and have the potential to revolutionize certain traditional design concepts. This produces the foremost motivation of this book: to equip engineers with the fundamental knowledge of CS and demonstrate its strong potential in wireless networking fields. Secondly, understanding a large portion of the

existing CS results in the literature requires a good mathematical background, but this book is written at a level for the engineers. Most parts of this book are suitable for readers who want to broaden their views, and it is also very useful for engineers and researchers in applied fields who deal with sampling problems in their work.

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