Preface

A considerable amount of data has been collected over the past several decades on the cellular, physiological, and anatomical properties of the brain. However, with the exception of a few notable early efforts, it is only in recent years that concerted attempts have been made to link the distinctive properties of the brain to concrete computational principles. In our view, an especially promising computational approach has been the use of probabilistic principles such as maximum likelihood and Bayesian inference to derive efficient algorithms for learning and perception. Our enthusiasm for this approach is based in part on some of its recent demonstrated successes, for example:

- The application of efficient coding algorithms to natural signals has been shown to generate receptive field properties similar to those observed in the nervous system.
- The instantiation of these algorithms in the form of "analysis-synthesis" loops has suggested functional models for the reciprocal feedforward-feedback connections between cortical areas.
- The theory of Bayesian belief propagation in probabilistic networks has yielded robust models for perceptual inference and allowed for a functional interpretation of several intriguing visual illusions and perceptual phenomena.

This book presents a representative sampling of some of the current probabilistic approaches to understanding perception and brain function. The book originated from a workshop on *Statistical Theories of Cortical Function* held in Breckenridge, Colorado, as part of the Neural Information Processing Systems (NIPS) conference in December, 1998. The goal of the workshop was to bring together researchers interested in exploring the use of well-defined statistical principles in understanding cortical structure and function. This book contains chapters written by many of the speakers from the NIPS workshop, as well as invited contributions from other leading researchers in the field. The topics include probabilistic and information theoretic models of perception, theories of neural coding and spike timing, computational models of lateral and cortico-cortical feedback connections, and the development of receptive field properties from natural signals.

While books with the words "brain" and "model" (or any of its cognates) in their title abound, one of the attributes that we feel sets the present book apart from many of its predecessors is its emphasis on the use of well-established probabilistic principles in interpreting data and constructing models. A second unique attribute is the attempt to present within a single volume both top-down computational models and bottom-up neurally-motivated models of brain function. This allows the similarities between these two types of approaches to be appreciated. To facilitate these connections, chapters containing related topics have been cross-referenced by the authors as much as possible. The introductory chapter provides an overview of the field and summarizes the contents of each chapter. A list of open problems and contentious issues is included at the end of this chapter to encourage new researchers to join in the effort and help infuse new ideas and techniques into the field.

We expect the book to be of interest to students and researchers in computational and cognitive neuroscience, psychology, statistics, information theory, artificial intelligence, and machine learning. Familiarity with elementary probability and statistics, together with some knowledge of basic neurobiology and vision, should prove sufficient in understanding much of the book.

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