Preface

In most data recording systems and many data communication systems, some sequences are more prone to error than others. Thus, in order to reduce the likelihood of error, it makes sense to impose a constraint on the sequences that are allowed to be recorded or transmitted. Given such a constraint, it is then necessary to encode arbitrary user sequences into sequences that obey the constraint. In this text, we develop a theory of constrained systems of sequences and encoder design for such systems. As a part of this, we include concrete examples and specific algorithms.

We begin in Chapter 1 with a description of several applications of constrained systems of sequences in data recording and data communications. We also give a rough description of the kinds of encoders and corresponding decoders that we will consider. Chapter 2 contains the basic mathematical concepts regarding constrained systems of sequences. Many of these concepts are closely related to fundamental notions in computer science, such as directed graphs and finite-state machines. In Chapter 3, we develop the notion of capacity from three different points of view: combinatorial, algebraic and probabilistic. In the course of doing so, we show how to compute the capacity of an arbitrary constrained system. In Chapter 4 we give a general introduction to finite-state encoders and sliding-block decoders. This includes Shannon's fundamental result that relates the maximal code rate of an encoder for a constrained system to the capacity of a constrained system. In Chapter 5, we develop the state-splitting algorithm, which gives a rigorous procedure for designing finite-state encoders for constrained systems.

There are many other ways of designing encoders for constrained systems. In Chapter 6, we outline some of these techniques and briefly explain how they are related to the state-splitting algorithm. In Chapter 7, we focus on complexity issues and finite procedures relating to encoders and decoders for constrained systems. For instance, we give bounds on the number of states in the smallest encoder for a given constrained system at a given rate. In Chapter 8 we begin with a very brief introduction to error-correction coding, in particular Reed-Solomon codes. We then discuss methods of concatenating constrained codes with error-correction codes. Finally, in Chapter 9 we consider codes which simultaneously have error-correction and constrained properties. These include spectral null codes and forbidden list codes which eliminate likely error events for specific channels. We also extend classical bounds for error-correction codes to combined error-correction–constrained codes.

This text is intended for graduate students and advanced undergraduates in electrical engineering, mathematics and computer science. The main prerequisites are elementary linear algebra and elementary probability at the undergraduate level. It is also helpful, but not necessary, to have had some exposure to information theory (for Chapter 3) and error-correction coding (for Chapters 8 and 9). While Chapter 1 includes discussion of several engineering applications, the remainder of the text develops the theory in a more formal mathematical manner.

We are happy to acknowledge that earlier versions of this text were used as notes for courses on Constrained Systems. One of these versions appeared as Chapter 20 of the Handbook of Coding Theory [PH98]. We are grateful to students, as well as many of our colleagues in industry and universities, for helpful suggestions on these earlier versions.