

## **Engineering Tripos Part IIA, 3F7: Information Theory and Coding, 2019-20**

### **Leader**

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### **Lecturer**

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### **Lab Leader**

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### **Timing and Structure**

Michaelmas Term. 16 lectures. Assessment: 100% exam

### **Aims**

The aims of the course are to:

- To introduce students to the principles of information theory, data compression, and error-correction, which form the foundations of modern communication and information processing systems.

### **Objectives**

As specific objectives, by the end of the course students should be able to:

- Explain why entropy and channel capacity arise as fundamental limits for data compression and transmission, respectively
- Understand and implement basic compression algorithms such as Huffman coding and Arithmetic coding
- Encode and decode information using simple linear block codes
- Implement decoding algorithms for modern error-correcting codes such as LDPC codes

### **Content**

#### **Information Theory and Data Compression (11L)**

1. Probability fundamentals; Definitions of entropy, joint entropy, conditional entropy: interpretations as measures of uncertainty
2. Noiseless source coding theorem; Significance of entropy as the fundamental limit of compression
3. Bounds on code length for lossless data compression
4. Practical compression algorithms: Huffman coding, Arithmetic coding
5. Relative Entropy, Mutual Information: Properties and some applications
6. Discrete Memoryless Channels and Channel Capacity

7. The channel coding theorem: Random coding and the direct coding theorem; Fano's inequality and the converse theorem
8. The additive white Gaussian noise (AWGN) channel and its capacity

### Channel Coding (Error-correcting codes) (5L)

1. Introduction to block codes; Linear block codes
2. Representing a linear code using a factor graph; Sparse-graph codes
3. Message passing decoding of sparse-graph codes for binary erasure channels
4. The Belief Propagation (BP) algorithm; BP decoding of sparse-graph codes for general binary input channels

### Further notes

This module will be of interest to anyone who wishes to understand how information can be mathematically modelled, measured, compressed, and transmitted. Though not a pre-requisite for 3F4, 3F7 provides a good foundation for further study of digital communications.

### Coursework

#### Data Compression: Build your own CamZIP

##### Learning objectives:

- To implement various data compression algorithms in Python/Matlab/Octave
- To compare the compression performance of different techniques on text files
- To understand the effects of finite precision implementation on the compression performance of arithmetic coding

##### Practical information:

- Students can do the lab in their own time. Scheduled 'helpdesk' sessions will be held in DPO during Michaelmas term (times will be announced on Moodle)

##### Full Technical Report:

Students will have the option to submit a Full Technical Report.

### Booklists

The following are useful references:

- T. Cover and J. Thomas, *Elements of Information Theory*, Wiley-Blackwell, 2006.
- D. MacKay, *Information Theory, Inference and Learning Algorithms*, Cambridge University Press, 2003 (free electronic copy available for download)
- T. Richardson and R. Urbanke, *Modern Coding Theory*, Cambridge University Press, 2008.
- R. Blahut, *Algebraic Codes for Data Transmission*, Cambridge University Press, 2012.

### Examination Guidelines

Please refer to [Form & conduct of the examinations](#) [3].

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#### **Links**

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