Preface xi

0 Introduction 1

0.1 Background 1

0.2 Perspective 4

0.3 Tools 7

0.4 What is a communication? 8

I A FOUNDATION COURSE IN CSP 11

1 Fundamental concepts 13

1.1 Fundamental operators 14

1.2 Algebra 29

1.3 The traces model and traces refinement 35

1.4 Tools 48

2 Parallel operators 51

2.1 Synchronous parallel 51

2.2 Alphabetized parallel 55

2.3 Interleaving 65

2.4 Generalized parallel 68

2.5 Parallel composition as conjunction 70
2.6 Tools 74
2.7 Postscript: On alphabets 76

3 Hiding and renaming **77**
3.1 Hiding 77
3.2 Renaming and alphabet transformations 86
3.3 A basic guide to failures and divergences 92
3.4 Tools 98

4 Piping and enslavement **99**
4.1 Piping 99
4.2 Enslavement 105
4.3 Tools 109

5 Buffers and communication **113**
5.1 Pipes and buffers 113
5.2 Buffer tolerance 125
5.3 The alternating bit protocol 128
5.4 Tools 133

6 Termination and sequential composition **135**
6.1 What is termination? 135
6.2 Distributed termination 139
6.3 Laws 140
6.4 Effects on the traces model 143
6.5 Effects on the failures/divergences model 144

II THEORY **147**

7 Operational semantics **149**
7.1 A survey of semantic approaches to CSP 149
7.2 Transition systems and state machines 151
7.3 Firing rules for CSP 158

7.4 Relationships with abstract models 170
7.5 Tools 177
7.6 Notes 178

8 Denotational semantics 179
8.1 Introduction 179
8.2 The traces model 182
8.3 The failures/divergences model 191
8.4 The stable failures model 207
8.5 Notes 214

9 Analyzing the denotational models 217
9.1 Deterministic processes 217
9.2 Analyzing fixed points 223
9.3 Full abstraction 228
9.4 Relations with operational semantics 238
9.5 Notes 243

10 Infinite traces 245
10.1 Calculating infinite traces 245
10.2 Adding failures 251
10.3 Using infinite traces 258
10.4 Notes 267

11 Algebraic semantics 269
11.1 Introduction 269
11.2 Operational semantics via algebra 271
11.3 The laws of $\perp_{\mathcal{N}}$ 275
11.4 Normalizing 277
11.5 Sequential composition and *SKIP* 286
11.6 Other models 290
11.7 Notes 292

12 Abstraction 295
12.1 Modes of abstraction 296
12.2 Reducing specifications 306
12.3 Abstracting errors: specifying fault tolerance 309
12.4 Independence and security 316
12.5 Tools 325
12.6 Notes 326

III PRACTICE 329

13 Deadlock! 331
13.1 Basic principles and tree networks 331
13.2 Specific ways to avoid deadlock 343
13.3 Variants 358
13.4 Network decomposition 370
13.5 The limitations of local analysis 373
13.6 Deadlock and tools 375
13.7 Notes 380

14 Modelling discrete time 383
14.1 Introduction 383
14.2 Meeting timing constraints 384
14.3 Case study 1: level crossing gate 388
14.4 Checking untimed properties of timed processes 398
14.5 Case study 2: the alternating bit protocol 403
14.6 Urgency and priority 409
14.7 Tools 412
14.8 Notes 413

15 Case studies 415
15.1 Combinatorial systems: rules and tactics 416
15.2 Distributed data and data-independence 422
15.3 Breaking crypto-protocols 446
15.4 Notes 464

A Mathematical background **467**
A.1 Partial orders 467
A.2 Metric spaces 486

B A guide to machine-readable CSP **495**
B.1 Introduction 495
B.2 Expressions 496
B.3 Pattern matching 502
B.4 Types 504
B.5 Processes 508
B.6 Special definitions 511
B.7 Mechanics 514
B.8 Missing features 515
B.9 Availability 515

C The operation of FDR **517**
C.1 Basic operation 517
C.2 Hierarchical compression 528

Notation **539**

Bibliography **543**

Main index **551**

Index of named processes **563**