

# Contents

<b>1</b>	<b>Introduction</b> . . . . .	1
1.1	How the Book is Organized . . . . .	3
1.1.1	From Metrology to Digital Data . . . . .	3
1.1.2	Uncertainty, Information, and Learning Mechanisms . . . . .	4
1.1.3	Randomized Algorithms . . . . .	5
1.1.4	Robustness Analysis . . . . .	6
1.1.5	Emotional Cognitive Mechanisms for Embedded Systems . . . . .	7
1.1.6	Performance Estimation and Probably Approximately Correct Computation . . . . .	7
1.1.7	Intelligent Mechanisms in Embedded Systems . . . . .	8
1.1.8	Learning in Nonstationary and Evolving Environments . . . . .	9
1.1.9	Fault Diagnosis Systems . . . . .	10
<b>2</b>	<b>From Metrology to Digital Data</b> . . . . .	11
2.1	Measure and Measurements . . . . .	11
2.1.1	The Measurement Chain . . . . .	12
2.1.2	Modeling the Measurement Process . . . . .	15
2.1.3	Accuracy . . . . .	16
2.1.4	Precision . . . . .	18
2.1.5	Resolution . . . . .	19
2.2	A Deterministic Versus a Stochastic Representation of Data . . . . .	20
2.2.1	A Deterministic Representation: Noise-Free Data . . . . .	20
2.2.2	A Stochastic Representation: Noise-Affected Data . . . . .	21
2.2.3	The Signal-to-Noise Ratio . . . . .	22
<b>3</b>	<b>Uncertainty, Information, and Learning Mechanisms</b> . . . . .	25
3.1	Uncertainty and Perturbations . . . . .	25
3.1.1	From Errors to Perturbations . . . . .	25
3.1.2	Perturbations . . . . .	26

- 3.2 Perturbations at the Data Representation Level . . . . . 27
  - 3.2.1 Natural Numbers  $\mathbb{N}$ : Binary Natural . . . . . 27
  - 3.2.2 Integer Numbers  $\mathbb{Z}$ : 2's Complement . . . . . 29
  - 3.2.3 2cp Notation . . . . . 29
  - 3.2.4 Rational  $\mathbb{Q}$  and Real  $\mathbb{R}$  Numbers . . . . . 30
- 3.3 Propagation of Uncertainty . . . . . 32
  - 3.3.1 Linear Functions. . . . . 32
  - 3.3.2 Nonlinear Functions . . . . . 37
- 3.4 Learning from Data and Uncertainty at the Model Level. . . . . 38
  - 3.4.1 Basics of Learning: Inherent, Approximation, and Estimation Risks . . . . . 38
  - 3.4.2 The Bias-Variance Tradeoff. . . . . 42
  - 3.4.3 Nonlinear Regression . . . . . 45
  - 3.4.4 Linear Regression. . . . . 47
  - 3.4.5 Linear Time-Invariant Predictive Models. . . . . 49
  - 3.4.6 Uncertainty at the Application Level. . . . . 51
- 4 Randomized Algorithms . . . . . 53**
  - 4.1 Computational Complexity . . . . . 54
    - 4.1.1 Analysis of Algorithms . . . . . 55
    - 4.1.2 P, NP-Complete, and NP-Hard Problems. . . . . 57
  - 4.2 Monte Carlo . . . . . 59
    - 4.2.1 The Idea Behind Monte Carlo . . . . . 59
    - 4.2.2 Weak and Strong Laws of Large Numbers . . . . . 62
    - 4.2.3 Some Convergence Results . . . . . 64
    - 4.2.4 The Curse of Dimensionality and Monte Carlo . . . . . 67
  - 4.3 Bounds on the Number of Samples. . . . . 67
    - 4.3.1 The Bernoulli Bound . . . . . 68
    - 4.3.2 The Chernoff Bound. . . . . 69
    - 4.3.3 A Bound on Samples to Estimate the Maximum Value of a Function . . . . . 74
  - 4.4 Randomized Algorithms . . . . . 76
    - 4.4.1 The Algorithm Verification Problem. . . . . 77
    - 4.4.2 The Maximum Value Estimation Problem. . . . . 80
    - 4.4.3 The Expectation Estimation Problem . . . . . 84
    - 4.4.4 The Minimum (Maximum) Expectation Problem . . . . . 87
  - 4.5 Controlling the Statistical Volume of the Sampling Space. . . . . 91
- 5 Robustness Analysis . . . . . 95**
  - 5.1 Problem Formalization . . . . . 96
    - 5.1.1 Robustness. . . . . 96
    - 5.1.2 Robustness at the Computational Flow Level. . . . . 97

5.2	Robustness in the Small . . . . .	99
5.2.1	Evaluating the Impact of Small Perturbations at the Function Output . . . . .	99
5.2.2	Perturbations at the Empirical Risk Level . . . . .	99
5.2.3	Perturbations at the Structural Risk Level . . . . .	105
5.2.4	Theory Highlights on Robustness . . . . .	111
5.3	Robustness in the Large . . . . .	114
5.3.1	Problem Definition: The $u(\delta\theta)$ Case . . . . .	114
5.3.2	Randomized Algorithms and Robustness: The $u(\delta\theta)$ Case . . . . .	116
5.3.3	The Maximum Expectation Problem . . . . .	119
<b>6</b>	<b>Emotional Cognitive Mechanisms for Embedded Systems . . . . .</b>	<b>123</b>
6.1	Emotional Cognitive Structure . . . . .	124
6.2	Automatic and Controlled Processes . . . . .	125
6.2.1	Automatic Processes . . . . .	125
6.2.2	Controlled Processes . . . . .	126
6.3	Basic Functions of the Neural Emotional System . . . . .	127
6.3.1	Amygdala . . . . .	128
6.3.2	Long-Term Memory . . . . .	128
6.3.3	Basal Ganglia . . . . .	129
6.3.4	Lateral Prefrontal and Association Cortices . . . . .	129
6.3.5	Anterior Cingulate Cortex . . . . .	130
6.3.6	Orbital and Ventral-Medial Prefrontal Cortices . . . . .	130
6.3.7	Hippocampus . . . . .	131
6.4	Emotion and Decision-Making . . . . .	131
<b>7</b>	<b>Performance Estimation and Probably Approximately Correct Computation . . . . .</b>	<b>133</b>
7.1	Accuracy Estimation: Figures of Merit . . . . .	134
7.1.1	Squared Error . . . . .	135
7.1.2	Kullback–Leibler . . . . .	136
7.1.3	$L^p$ Norms and Other Figures of Merit . . . . .	136
7.2	Probably Approximately Correct Computation . . . . .	137
7.3	The Performance Verification Problem . . . . .	140
7.3.1	The Performance Satisfaction Problem . . . . .	141
7.3.2	The Figure of Merit Expectation Problem . . . . .	143
7.3.3	The Maximum Performance Problem . . . . .	143
7.3.4	The PACC Problem . . . . .	144
7.3.5	The Minimum (Maximum)-Perturbed Expectation Problem . . . . .	145

7.4	Accuracy Estimation: A Given Dataset Case . . . . .	146
7.4.1	Problem Formalization . . . . .	147
7.4.2	The Bootstrap Method. . . . .	147
7.4.3	The Bag of Little Bootstraps Method . . . . .	149
7.5	Cognitive Processes and PACC . . . . .	150
7.6	Example: Accuracy Assessment in Embedded Systems. . . . .	150
<b>8</b>	<b>Intelligent Mechanisms in Embedded Systems . . . . .</b>	<b>159</b>
8.1	Adaptation at the Power Supply Voltage and Processor Frequency Levels. . . . .	161
8.1.1	Online DVFS . . . . .	162
8.1.2	Offline DVFS . . . . .	164
8.2	Adaptive Sensing and its Policies . . . . .	165
8.2.1	Hierarchical Sensing Techniques . . . . .	167
8.2.2	Adaptive Sampling . . . . .	170
8.3	Adaptation at the Energy Harvesting Level . . . . .	172
8.3.1	The Incremental Conductance Approach . . . . .	177
8.3.2	The Perturb and Observe Approach . . . . .	177
8.4	Intelligent Algorithms for Clock Synchronization. . . . .	179
8.4.1	Clock Synchronization: The Framework . . . . .	182
8.4.2	Statistic Methods for Clock Synchronization . . . . .	183
8.4.3	Adaptive Methods for Clock Synchronization . . . . .	189
8.4.4	Predictive Methods for Clock Synchronization. . . . .	189
8.5	Localization and Tracking . . . . .	189
8.5.1	RSS-Based Localization . . . . .	190
8.5.2	Time-of-Arrival Based Localization . . . . .	193
8.5.3	Angle-of-Arrival Based Localization. . . . .	195
8.5.4	Frequency-of-Arrival Based Method. . . . .	195
8.6	Adaptation at the Application Code Level. . . . .	196
8.6.1	Remote Parametric-Code Reprogrammability. . . . .	197
8.6.2	Remote Code Reprogrammability. . . . .	198
8.6.3	Decision Support System. . . . .	199
8.6.4	Online Hardware Reprogrammability . . . . .	203
8.6.5	An Application: The Rialba Monitoring System. . . . .	206
<b>9</b>	<b>Learning in Nonstationary and Evolving Environments . . . . .</b>	<b>211</b>
9.1	Passive and Active Learning . . . . .	213
9.1.1	Passive Learning . . . . .	213
9.1.2	Active Learning . . . . .	216
9.2	Change Point Methods . . . . .	220
9.2.1	Change Points . . . . .	222
9.2.2	Set Dissimilarity. . . . .	222
9.2.3	The Change Point Formulation. . . . .	223
9.2.4	Test Statistics Used in CPMs. . . . .	225
9.2.5	Extensions Over the Basic Scheme. . . . .	226

- 9.3 Change Detection Tests. . . . . 227
  - 9.3.1 The CUSUM CDT Family. . . . . 227
  - 9.3.2 The Intersection of Confidence Intervals  
CDT Family . . . . . 231
  - 9.3.3 Amygdala—VM-PFC: The H-CDT. . . . . 238
- 9.4 The Just-in-Time Learning Framework . . . . . 239
  - 9.4.1 Observation Model . . . . . 240
  - 9.4.2 The JIT Classifier. . . . . 241
  - 9.4.3 Gradual Concept Drift. . . . . 245
  - 9.4.4 JIT for Gradual Concept Drift . . . . . 246
  - 9.4.5 Amygdala—VM-PFC—LPAC- ACC:  
The JIT Approach . . . . . 247
- 10 Fault Diagnosis Systems . . . . . 249**
  - 10.1 Model-Based Fault Detection and Isolation . . . . . 252
  - 10.2 Model-Free Fault Detection and Isolation . . . . . 253
    - 10.2.1 FDS: The Sensor Level Case . . . . . 255
    - 10.2.2 FDS: Changes in a Sensor–Sensor Relationship . . . . . 260
    - 10.2.3 FDS: The Multi Sensors Case . . . . . 265
  - 10.3 Amygdala and VM-PFC: FDS at the Multi Sensor Level . . . . . 270
- References . . . . . 271**
- Index . . . . . 281**



<http://www.springer.com/978-3-319-05277-9>

Intelligence for Embedded Systems

A Methodological Approach

Alippi, C.

2014, XIX, 283 p. 81 illus., 73 illus. in color., Hardcover

ISBN: 978-3-319-05277-9