

# Table of Contents

<b>1. Introduction and Overview</b>	1
1.1 Why Integrate Neurons and Symbols?	1
1.2 Strategies of Neural-Symbolic Integration	3
1.3 Neural-Symbolic Learning Systems	5
1.4 A Simple Example	7
1.5 How to Read this Book	10
1.6 Summary	12
<b>2. Background</b>	13
2.1 General Preliminaries	13
2.2 Inductive Learning	14
2.3 Neural Networks	15
2.3.1 Architectures	16
2.3.2 Learning Strategy	19
2.3.3 Recurrent Networks	21
2.4 Logic Programming	23
2.4.1 What is Logic Programming?	23
2.4.2 Fixpoints and Definite Programs	26
2.5 Nonmonotonic Reasoning	29
2.5.1 Stable Models and Acceptable Programs	29
2.6 Belief Revision	34
2.6.1 Truth Maintenance Systems	37
2.6.2 Compromise Revision	39

---

## Part I. Knowledge Refinement in Neural Networks

---

<b>3. Theory Refinement in Neural Networks</b>	43
3.1 Inserting Background Knowledge	44
3.2 Massively Parallel Deduction	56
3.3 Performing Inductive Learning	58
3.4 Adding Classical Negation	59

3.5	Adding Metalevel Priorities .....	64
3.6	Summary and Further Reading .....	84
<b>4.</b>	<b>Experiments on Theory Refinement .....</b>	<b>87</b>
4.1	DNA Sequence Analysis .....	87
4.2	Power Systems Fault Diagnosis .....	97
4.3	Discussion .....	106
4.4	Appendix .....	108

---

## Part II. Knowledge Extraction from Neural Networks

---

<b>5.</b>	<b>Knowledge Extraction from Trained Networks .....</b>	<b>113</b>
5.1	The Extraction Problem .....	114
5.2	The Case of Regular Networks .....	120
5.2.1	Positive Networks .....	121
5.2.2	Regular Networks .....	127
5.3	The General Case Extraction .....	137
5.3.1	Regular Subnetworks .....	138
5.3.2	Knowledge Extraction from Subnetworks .....	139
5.3.3	Assembling the Final Rule Set .....	151
5.4	Knowledge Representation Issues .....	153
5.5	Summary and Further Reading .....	155
<b>6.</b>	<b>Experiments on Knowledge Extraction .....</b>	<b>159</b>
6.1	Implementation .....	159
6.2	The Monk's Problems .....	166
6.3	DNA Sequence Analysis .....	168
6.4	Power Systems Fault Diagnosis .....	173
6.5	Discussion .....	176

---

## Part III. Knowledge Revision in Neural Networks

---

<b>7.</b>	<b>Handling Inconsistencies in Neural Networks .....</b>	<b>183</b>
7.1	Theory Revision in Neural Networks .....	183
7.1.1	The Equivalence with Truth Maintenance Systems ....	184
7.1.2	Minimal Learning .....	186
7.2	Solving Inconsistencies in Neural Networks .....	192
7.2.1	Compromise Revision .....	194
7.2.2	Foundational Revision .....	195
7.2.3	Nonmonotonic Theory Revision .....	200
7.3	Summary of the Chapter .....	207

<b>8. Experiments on Handling Inconsistencies</b> .....	209
8.1 Requirements Specifications Evolution as Theory Refinement	209
8.1.1 Analysing Specifications .....	209
8.1.2 Revising Specifications .....	212
8.2 The Automobile Cruise Control System .....	215
8.2.1 Knowledge Insertion .....	217
8.2.2 Knowledge Revision: Handling Inconsistencies .....	219
8.2.3 Knowledge Extraction .....	223
8.3 Discussion .....	228
8.4 Appendix .....	230
<b>9. Neural-Symbolic Integration: The Road Ahead</b> .....	235
9.1 Knowledge Extraction .....	237
9.2 Adding Disjunctive Information .....	240
9.3 Extension to the First-Order Case .....	244
9.4 Adding Modalities .....	245
9.5 New Preference Relations .....	247
9.6 A Proof Theoretical Approach .....	249
9.7 The “Forbidden Zone” $[A_{\max}, A_{\min}]$ .....	250
9.8 Acceptable Programs and Neural Networks .....	250
9.9 Epilogue .....	252
<b>References</b> .....	253
<b>Index</b> .....	267



<http://www.springer.com/978-1-85233-512-0>

Neural-Symbolic Learning Systems

Foundations and Applications

d'Avila Garcez, A.S.; Broda, K.; Gabbay, D.

2002, XIV, 271 p. 30 illus., Softcover

ISBN: 978-1-85233-512-0