

Contents

Preface *ix*

Acknowledgments *xv*

1 Empirical Research *1*

- 1.1 AI Programs as Objects of Empirical Studies *2*
- 1.2 Three Basic Research Questions *4*
- 1.3 Answering the Basic Research Questions *5*
- 1.4 Kinds of Empirical Studies *6*
- 1.5 A Prospective View of Empirical Artificial Intelligence *9*

2 Exploratory Data Analysis *11*

- 2.1 Data *12*
- 2.2 Sketching a Preliminary Causal Model *18*
- 2.3 Looking at One Variable *20*
- 2.4 Joint Distributions *27*
- 2.5 Time Series *53*
- 2.6 Execution Traces *62*

3 Basic Issues in Experiment Design *67*

- 3.1 The Concept of Control *68*
- 3.2 Four Spurious Effects *79*
- 3.3 Sampling Bias *89*

3.4	The Dependent Variable	92
3.5	Pilot Experiments	94
3.6	Guidelines for Experiment Design	96
3.7	Tips for Designing Factorial Experiments	97
3.8	The Purposes of Experiments	100
3.9	Ecological Validity: Making Experiments Relevant	101
3.10	Conclusion	103
4	Hypothesis Testing and Estimation	105
4.1	Statistical Inference	106
4.2	Introduction to Hypothesis Testing	106
4.3	Sampling Distributions and the Hypothesis Testing Strategy	110
4.4	Tests of Hypotheses about Means	117
4.5	Hypotheses about Correlations	130
4.6	Parameter Estimation and Confidence Intervals	132
4.7	How Big Should Samples Be?	137
4.8	Errors	140
4.9	Power Curves and How to Get Them	143
4.10	Conclusion	145
4.11	Further Reading	146
5	Computer-Intensive Statistical Methods	147
5.1	Monte Carlo Tests	150
5.2	Bootstrap Methods	153
5.3	Randomization Tests	165
5.4	Comparing Bootstrap and Randomization Procedures	175
5.5	Comparing Computer-Intensive and Parametric Procedures	177
5.6	Jackknife and Cross Validation	180
5.7	An Illustrative Nonparametric Test: The Sign Test	180
5.8	Conclusion	182
5.9	Further Reading	183

6	Performance Assessment	185
6.1	Strategies for Performance Assessment	186
6.2	Assessing Performance in Batches of Trials	187
6.3	Comparisons to External Standards: The View Retriever	187
6.4	Comparisons among Many Systems: The MUC-3 Competition	199
6.5	Comparing the Variability of Performance: Humans vs. the View Retriever	205
6.6	Assessing Whether a Factor Has Predictive Power	207
6.7	Assessing Sensitivity: MYCIN's Sensitivity to Certainty Factor Accuracy	208
6.8	Other Measures of Performance in Batches of Trials	210
6.9	Assessing Performance During Development: Training Effects in OTB	211
6.10	Cross-Validation: An Efficient Training and Testing Procedure	216
6.11	Learning Curves	219
6.12	Assessing Effects of Knowledge Engineering with Retesting	221
6.13	Assessing Effects with Classified Retesting: Failure Recovery in Phoenix	223
6.14	Diminishing Returns and Overfitting in Retesting	232
6.15	Conclusion	233
	Appendix: Analysis of Variance and Contrast Analysis	235
7	Explaining Performance: Interactions and Dependencies	249
7.1	Strategies for Explaining Performance	250
7.2	Interactions among Variables: Analysis of Variance	251
7.3	Explaining Performance with Analysis of Variance	260
7.4	Dependencies among Categorical Variables: Analysis of Frequencies	267
7.5	Explaining Dependencies in Execution Traces	268
7.6	Explaining More Complex Dependencies	270
7.7	General Patterns in Three-Way Contingency Tables	279
7.8	Conclusion	287

7.9	Further Reading	287
	Appendix: Experiment Designs and Analysis	287
8	Modeling	309
8.1	Programs as Models: Executable Specifications and Essential Miniatures	312
8.2	Cost as a Function of Learning: Linear Regression	316
8.3	Transforming Data for Linear Models	321
8.4	Confidence Intervals for Linear Regression Models	324
8.5	The Significance of a Predictor	327
8.6	Linear Models with Several Predictors: Multiple Regression	328
8.7	A Model of Plan Adaptation Effort	332
8.8	Causal Models	337
8.9	Structural Equation Models	342
8.10	Conclusion	347
8.11	Further Reading	347
	Appendix: Multiple Regression	348
9	Tactics for Generalization	359
9.1	Empirical Generalization	362
9.2	Theories and "Theory"	366
9.3	Tactics for Suggesting and Testing General Theories	369
9.4	Which Features?	375
9.5	Finding the "Same" Behavior in Several Systems	376
9.6	The Virtues of Theories of Ill-Defined Behavior	378

References	385
Index	395