
Contents

| | |
|---|--------------|
| Foreword | xi |
| Preface | xiii |
| Acknowledgements | xv |
| List of Figures | xvii |
| List of Tables | xxi |
| List of Examples | xxiii |
| List of Definitions | xxvii |
| List of Theorems | xxix |
| List of Abbreviations | xxxii |
| 1 Preliminaries | 1 |
| 1.1 Orders, Lattices, Ordinals | 1 |
| 1.2 Mappings and Fixpoints | 3 |
| 1.3 Logic Programming | 4 |
| 1.4 Semantics for Normal Logic Programs | 13 |
| 1.4.1 Program Completion | 13 |
| 1.4.2 Well-Founded Semantics | 15 |
| 1.4.3 Stable Model Semantics | 21 |
| 1.5 Probability Theory | 23 |
| 1.6 Probabilistic Graphical Models | 32 |

| | | |
|----------|--|------------|
| 2 | Probabilistic Logic Programming Languages | 41 |
| 2.1 | Languages with the Distribution Semantics | 41 |
| 2.1.1 | Logic Programs with Annotated Disjunctions | 42 |
| 2.1.2 | ProbLog | 43 |
| 2.1.3 | Probabilistic Horn Abduction | 43 |
| 2.1.4 | PRISM | 44 |
| 2.2 | The Distribution Semantics for Programs Without Function Symbols | 45 |
| 2.3 | Examples of Programs | 50 |
| 2.4 | Equivalence of Expressive Power | 56 |
| 2.5 | Translation to Bayesian Networks | 58 |
| 2.6 | Generality of the Distribution Semantics | 62 |
| 2.7 | Extensions of the Distribution Semantics | 64 |
| 2.8 | CP-Logic | 66 |
| 2.9 | Semantics for Non-Sound Programs | 71 |
| 2.10 | KBMC Probabilistic Logic Programming Languages | 76 |
| 2.10.1 | Bayesian Logic Programs | 76 |
| 2.10.2 | CLP(BN) | 76 |
| 2.10.3 | The Prolog Factor Language | 79 |
| 2.11 | Other Semantics for Probabilistic Logic Programming | 80 |
| 2.11.1 | Stochastic Logic Programs | 81 |
| 2.11.2 | ProPPR | 82 |
| 2.12 | Other Semantics for Probabilistic Logics | 84 |
| 2.12.1 | Nilsson’s Probabilistic Logic | 84 |
| 2.12.2 | Markov Logic Networks | 84 |
| | 2.12.2.1 Encoding Markov Logic Networks with Probabilistic Logic Programming | 85 |
| 2.12.3 | Annotated Probabilistic Logic Programs | 88 |
| 3 | Semantics with Function Symbols | 91 |
| 3.1 | The Distribution Semantics for Programs with Function Symbols | 92 |
| 3.2 | Infinite Covering Set of Explanations | 97 |
| 3.3 | Comparison with Sato and Kameya’s Definition | 110 |
| 4 | Semantics for Hybrid Programs | 115 |
| 4.1 | Hybrid ProbLog | 115 |
| 4.2 | Distributional Clauses | 118 |
| 4.3 | Extended PRISM | 124 |

| | | |
|----------|---|------------|
| 4.4 | cplint Hybrid Programs | 126 |
| 4.5 | Probabilistic Constraint Logic Programming | 130 |
| 4.5.1 | Dealing with Imprecise Probability Distributions | 135 |
| 5 | Exact Inference | 145 |
| 5.1 | PRISM | 146 |
| 5.2 | Knowledge Compilation | 150 |
| 5.3 | ProbLog1 | 151 |
| 5.4 | cplint | 155 |
| 5.5 | SLGAD | 157 |
| 5.6 | PITA | 158 |
| 5.7 | ProbLog2 | 163 |
| 5.8 | T_P Compilation | 176 |
| 5.9 | Modeling Assumptions in PITA | 178 |
| 5.9.1 | PITA(OPT) | 181 |
| 5.9.2 | MPE with PITA | 186 |
| 5.10 | Inference for Queries with an Infinite Number of Explanations | 186 |
| 5.11 | Inference for Hybrid Programs | 187 |
| 6 | Lifted Inference | 195 |
| 6.1 | Preliminaries on Lifted Inference | 195 |
| 6.1.1 | Variable Elimination | 197 |
| 6.1.2 | GC-FOVE | 201 |
| 6.2 | LP ² | 202 |
| 6.2.1 | Translating ProbLog into PFL | 202 |
| 6.3 | Lifted Inference with Aggregation Parfactors | 205 |
| 6.4 | Weighted First-Order Model Counting | 207 |
| 6.5 | Cyclic Logic Programs | 210 |
| 6.6 | Comparison of the Approaches | 210 |
| 7 | Approximate Inference | 213 |
| 7.1 | ProbLog1 | 213 |
| 7.1.1 | Iterative Deepening | 213 |
| 7.1.2 | k -best | 215 |
| 7.1.3 | Monte Carlo | 216 |
| 7.2 | MCINTYRE | 218 |
| 7.3 | Approximate Inference for Queries with an Infinite Number of Explanations | 221 |

| | | |
|-----------|--|------------|
| 7.4 | Conditional Approximate Inference | 222 |
| 7.5 | Approximate Inference by Sampling for Hybrid Programs | 223 |
| 7.6 | Approximate Inference with Bounded Error for Hybrid Programs | 226 |
| 7.7 | k -Optimal | 229 |
| 7.8 | Explanation-Based Approximate Weighted Model Counting | 231 |
| 7.9 | Approximate Inference with T_P -compilation | 233 |
| 7.10 | DISTR and EXP Tasks | 234 |
| 8 | Non-Standard Inference | 239 |
| 8.1 | Possibilistic Logic Programming | 239 |
| 8.2 | Decision-Theoretic ProbLog | 241 |
| 8.3 | Algebraic ProbLog | 250 |
| 9 | Parameter Learning | 259 |
| 9.1 | PRISM Parameter Learning | 259 |
| 9.2 | LLPAD and ALLPAD Parameter Learning | 265 |
| 9.3 | LeProbLog | 267 |
| 9.4 | EMBLEM | 270 |
| 9.5 | ProbLog2 Parameter Learning | 280 |
| 9.6 | Parameter Learning for Hybrid Programs | 282 |
| 10 | Structure Learning | 283 |
| 10.1 | Inductive Logic Programming | 283 |
| 10.2 | LLPAD and ALLPAD Structure Learning | 287 |
| 10.3 | ProbLog Theory Compression | 289 |
| 10.4 | ProbFOIL and ProbFOIL+ | 290 |
| 10.5 | SLIPCOVER | 296 |
| 10.5.1 | The Language Bias | 296 |
| 10.5.2 | Description of the Algorithm | 296 |
| 10.5.2.1 | Function INITIALBEAMS | 298 |
| 10.5.2.2 | Beam Search with Clause Refinements | 300 |
| 10.5.3 | Execution Example | 301 |
| 10.6 | Examples of Datasets | 304 |
| 11 | cplint Examples | 305 |
| 11.1 | cplint Commands | 305 |
| 11.2 | Natural Language Processing | 309 |
| 11.2.1 | Probabilistic Context-Free Grammars | 309 |

| | | |
|-----------|--|------------|
| 11.2.2 | Probabilistic Left Corner Grammars | 310 |
| 11.2.3 | Hidden Markov Models | 311 |
| 11.3 | Drawing Binary Decision Diagrams | 313 |
| 11.4 | Gaussian Processes | 314 |
| 11.5 | Dirichlet Processes | 318 |
| 11.5.1 | The Stick-Breaking Process | 319 |
| 11.5.2 | The Chinese Restaurant Process | 322 |
| 11.5.3 | Mixture Model | 324 |
| 11.6 | Bayesian Estimation | 326 |
| 11.7 | Kalman Filter | 327 |
| 11.8 | Stochastic Logic Programs | 330 |
| 11.9 | Tile Map Generation | 332 |
| 11.10 | Markov Logic Networks | 334 |
| 11.11 | Truel | 335 |
| 11.12 | Coupon Collector Problem | 339 |
| 11.13 | One-Dimensional Random Walk | 341 |
| 11.14 | Latent Dirichlet Allocation | 342 |
| 11.15 | The Indian GPA Problem | 346 |
| 11.16 | Bongard Problems | 348 |
| 12 | Conclusions | 351 |
| | References | 353 |
| | Index | 375 |
| | About the Author | 387 |