

Contents

1	Introduction	1
1.1	Approaches for Relational Probabilistic Reasoning	2
1.2	Contributions and Structure of this Thesis	11
1.3	Previous Publications	15
2	Theoretical Background	19
2.1	Conventions of Notations	19
2.2	Probability Distributions	21
2.3	Syntax of Logics	23
2.4	Semantics of Logics	31
2.5	Probabilistic Inference	35
3	Computing the ME-Distribution Under Aggregating Semantics	39
3.1	Feature Functions and Satisfaction	39
3.2	The ME Optimization Problem for Aggregating Semantics . . .	42
3.3	Developing an Algorithm for Computing $ME_{\odot}$	45
3.3.1	Generalized Iterative Scaling	46
3.3.2	Normalized Form of the General ME Optimization Problem	47
3.3.3	Transforming the Optimization Problem	49
3.3.4	Normalized Optimization Problem for Aggregating Semantics	53
3.3.5	Algorithm $GIS_{\odot}^{basic}$: A Basic GIS Algorithm for $ME_{\odot}$. . .	56
3.3.6	Evaluation of the Algorithm $GIS_{\odot}^{basic}$	59
3.4	Representing $ME_{\odot}$ as Gibbs Distribution	62
3.4.1	Product Form and Alpha-Values	62
3.4.2	Algorithm $GIS_{\odot}^{\alpha}$: Computing the Alpha-Values of $ME_{\odot}$. . .	64
4	Handling Deterministic Conditionals	71
4.1	Deterministic Conditionals and Null-Worlds	71

4.2	Reducing the Optimization Problem to Potentially Positive Worlds	76
4.3	Exploiting the Reduced Optimization Problem	82
4.4	Algorithms IsPosWorld and PosWorlds : Computing the Potentially Positive Worlds	86
4.5	Algorithm $\text{GIS}_{\odot}^{\text{pos}}$: Allowing Deterministic Conditionals and Null-Worlds in the $\text{ME}_{\odot}$ Computation	89
4.6	Evaluation of the Algorithm $\text{GIS}_{\odot}^{\text{pos}}$	95
4.7	Benefits of Deterministic Conditionals	100
5	Improving the Computation of $\text{ME}_{\odot}$ by Exploiting Equivalent Worlds	103
5.1	Sizes and Complexity of Probabilistic Knowledge Base	104
5.2	va-Pairs and Conditional Impact	108
5.3	Algorithm CondImpact : Conditional Impact Caused by a World	118
5.4	Equivalence of Worlds	119
5.5	Feature Function Equivalence	125
5.6	Exploiting the Equivalence of Worlds	128
5.7	Algorithm EqClasses : Constructing the Equivalence Classes	132
5.8	Algorithm $\text{GIS}_{\odot}^{\equiv}$: Exploiting Equivalent Worlds for Computing $\text{ME}_{\odot}$	134
5.9	Evaluation of the Algorithm $\text{GIS}_{\odot}^{\equiv}$	141
6	Abstracting from Worlds and Working on Weighted Conditional Impacts (WCI)	143
6.1	Abstracting from Worlds	143
6.2	Feature Functions and Satisfaction Based on Weighted Conditional Impacts	148
6.3	Algorithm WCI_{gen} : Computing the Weighted Conditional Impacts of a Knowledge Base	150
6.4	Algorithm $\text{GIS}_{\odot}^{\text{WCI}}$: $\text{ME}_{\odot}$ Computation On Weighted Conditional Impacts	152
6.5	Evaluation of the Algorithms WCI_{gen} and $\text{GIS}_{\odot}^{\text{WCI}}$	157
6.6	Relating the Results to Equivalence Classes	161
6.7	Another View at the ME -Distribution on Conditional Impacts	162
7	Atomic Conditionals: A Basic Start on the Road to a More Efficient WCI Computation	169
7.1	WCI of a Single Conditional	170

7.2	Illustrating the va-Pairs of a Conditional as va-Matrix	172
7.3	Atomic Conditionals and the Syntactical Structure of Ground Instances	178
7.3.1	Structure of a Ground Instance Table	184
7.3.2	Sets of Atoms in the Ground Instances	189
7.4	From the Structure of Ground Instances to the Set of va-Pairs by Combinatorial Means	193
7.4.1	Satisfaction of Ground Atoms	194
7.4.2	Tuples and Combinations of Sat-Pairs	198
7.5	Combinatorially Determining the Weight of va-Pairs	218
7.6	Solving the Problem PROBWORLDNUM	226
7.6.1	Determining the Cardinality $ \mathcal{TS}\mathcal{P}_{\text{csp}}(CSP) $	230
7.6.2	Determining the Cardinality $ \Omega_{\text{tsp}}([CSP]_{\sigma}) $	233
7.6.3	Solution for the Problem PROBWORLDNUM	246
7.7	Algorithm WCI_{at} : Computing the WCI of an Atomic Condi- tional without Employing Worlds	252
7.8	Evaluation of the Algorithm WCI_{at}	256
7.8.1	Theoretical Running Time Analysis	256
7.8.2	Practical Evaluation of Examples	262
7.9	Extending the Developed Concepts to Non-Atomic Conditionals	271
7.9.1	Adding a Conjunction	271
7.9.2	Dealing with a Disjunction	281
7.9.3	Extending to Shared Variables and Arbitrary Formulas	281
7.9.4	Upcoming Challenges	284
8	Conclusions	289
	Bibliography	293
	Index	303