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Algorithms for Reasoning with Probabilistic Graphical Models

INTRODUCTORY

Summary

The course will cover the primary exact and approximate algorithms for reasoning with probabilistic graphical models (e.g., Bayesian and Markov networks, influence diagrams, and Markov decision processes). We will present inference-based, message passing schemes (e.g., variable elimination) and search-based, conditioning schemes (e.g., cycle-cutset conditioning and AND/OR search). Each algorithm class possesses distinct characteristics and in particular has different time vs. space behavior. We will emphasize the dependence of the methods on graph parameters such as the treewidth, cycle-cutset, and (pseudo-tree) height. We will start from exact algorithms and move to approximate schemes that are anytime, including weighted mini-bucket schemes with cost-shifting and MCMC sampling.

Syllabus

Class 1: Introduction and Inference schemes

- Basic Graphical models
 - Queries
 - Examples/applications/tasks
 - Algorithms overview
- Inference algorithms, exact
 - Bucket elimination
 - Jointree clustering
 - Elimination orders
- Decomposition Bounds
 - Dual Decomposition, GDD
 - MBE/WMBE
 - Belief Propagation

Class 2: Search Schemes

- AND/OR search spaces, pseudo-trees
 - AND/OR search trees
 - AND/OR search graphs
 - Generating good pseudo-trees
- Heuristic search for AND/OR spaces
 - Brute-force traversal
 - Depth-first AND/OR branch and bound
 - Best-first AND/OR search
 - The Guiding MBE heuristic
 - Marginal Map (max-sum-product)
- Hybrids of search and Inference

Class 3:

- Variational methods
 - Convexity & decomposition bounds
 - Variational forms & the marginal polytope
 - Message passing algorithms
 - Convex duality relationships
- Monte Carlo sampling
 - Basics
 - Importance sampling
 - Markov chain Monte Carlo
 - Integrating inference and sampling

References

Rina Dechter:

Reasoning with Probabilistic and Deterministic Graphical Models: Exact Algorithms. Synthesis Lectures on Artificial Intelligence and Machine Learning, Morgan & Claypool Publishers 2013

Alexander Ihler, Natalia Fierova, Rina Dechter, and Lars Otten. "Join-graph based cost-shifting schemes" in Proceedings of UAI 2012

Dechter, R. and Rish, I., "Mini-Buckets: A General Scheme for Bounded Inference" In "Journal of the ACM", Vol. 50, Issue 2: pages 107-153, March 2003.

Robert Mateescu, Kalev Kask, Vibhav Gogate, and Rina Dechter. "Join-Graph Propagation Algorithms." JAIR'2009

Pre-requisites

Basic Computer Science

Short-bio

Rina Dechter research centers on computational aspects of automated reasoning and knowledge representation including search, constraint processing, and probabilistic reasoning. She is a professor of computer science at the University of California, Irvine. She holds a Ph.D. from UCLA, an M.S. degree in applied mathematics from the Weizmann Institute, and a B.S. in mathematics and statistics from the

Hebrew University in Jerusalem. She is an author of *Constraint Processing* published by Morgan Kaufmann (2003), and *Reasoning with Probabilistic and Deterministic Graphical Models: Exact Algorithms* by Morgan and Claypool publishers, 2013, has co-authored over 150 research papers, and has served on the editorial boards of: *Artificial Intelligence*, the *Constraint Journal*, *Journal of Artificial Intelligence Research (JAIR)*, and *Journal of Machine Learning Research (JMLR)*. She is a fellow of the American Association of Artificial Intelligence 1994, was a Radcliffe Fellow 2005–2006, received the 2007 Association of Constraint Programming (ACP) Research Excellence Award, and she is a 2013 ACM Fellow. She has been Co-Editor-in-Chief of *Artificial Intelligence* since 2011. She is also co-editor with Hector Geffner and Joe Halpern of the book *Heuristics, Probability and Causality: A Tribute to Judea Pearl*, College Publications, 2010.

Alex Ihler is an associate professor of computer science at the University of California, Irvine. He received his MS and PhD degrees from the Massachusetts Institute of Technology in 2000 and 2005, and a BS from the California Institute of Technology in 1998. His research spans several areas of machine learning, with a particular focus on probabilistic, graphical model representations, including Bayesian networks, Markov random fields, and influence diagrams, and with applications to domains such as sensor networks, computer vision, and computational biology. He is the co-author of over 60 research papers, and the recipient of an NSF CAREER award. He is the director of UC Irvine's Center for Machine Learning, and has served on the editorial boards of *Machine Learning (MLJ)*, *Artificial Intelligence (AIJ)*, and the *Journal of Machine Learning Research (JMLR)*.