Uncertainty in Artificial Intelligence Research Overview for Graduate Student Day

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Overview

- What is Uncertainty in Artificial Intelligence (UAI)?

- Basics of Bayesian Networks

- UAI at USC

- Thesis Topics

- Some Words of Advice

What is UAI? A Taxonomy of AI

- Artificial Intelligence
  - (Robotics)
  - Automated Reasoning
    - (Theorem Proving)
    - Reasoning Under Uncertainty (UAI)
      - (Fuzzy Logic, Possibility Theory, Dempster-Shafer Theory)
      - Normative Systems (Based on Probability Theory and the Maximum Expected Utility Principle)
        - Bayesian Networks
        - Decision Networks (Influence Diagrams)
        - Decision Trees

The Birth of UAI

Modern UAI as a research area was born about seventeen years ago, through the effort of Judea Pearl, a Computer Science professor at the University of California at Los Angeles.

Immediately after, a decisive impulse to the development of Bayesian networks came from ESPRIT project P599, “A Knowledge-Based Assistant for Electromyography,” commonly known as the MUNIN project, which ran from January 1985 through June 1989.

ESPRIT was the European Strategic Program for Research and Development in Information Technologies.

Probabilistic Approaches to UAI

Here is a quote from the final report of the MUNIN project (July 30, 1989).

> Performance problems with [Bayesian networks] accelerated the development of a new theory which makes a previously untractable problem tractable. This was accomplished mainly due to the introduction of belief universes and is a significant scientific achievement. The theory is not limited to MUNIN nor to medical expert systems. The entire approach is a new and promising frame for expert systems dealing with domains with causal uncertainty. . . . A spin-off from this project has been the development of a CPN shell called HUGIN. HUGIN will be presented at IJCAI, Detroit, in August 1989.

The Uncertainty in AI Conference

Uncertainty in Artificial Intelligence is also the name of an annual international conference.

UAI-2000 was the sixteenth conference on uncertainty in Artificial Intelligence.

Rarely has a subfield of Artificial Intelligence enjoyed such a dominant conference. Besides serving as a forum for the exchange of ideas and results, the conference is also a place for discussion of terminology and possible emerging standards.

Bayesian Networks

> "Contrary to most other frameworks for handling uncertainty, a good deal of theoretical insight as well as practical experience is required in order to exploit the opportunities provided by Bayesian networks and decision [networks]" (Jensen, 2000).

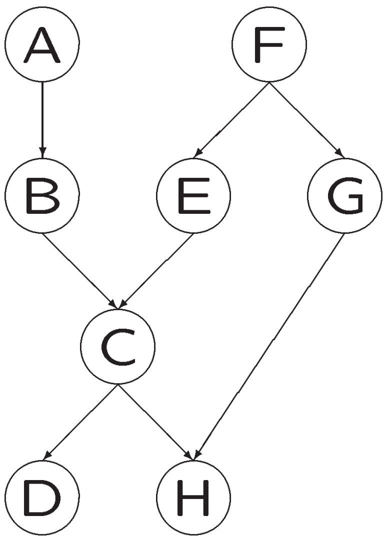
A Bayesian network is analogous to a program in Prolog, because it is both

- a "program" to compute beliefs, and
- a specification of a joint probability distribution.

The Dyspnoea Example

"Tuberculosis and lung cancer can cause shortness of breath (dyspnoea) with equal likelihood. The same is true for a positive chest X-Ray (i.e., positive chest X-Ray is also equally likely given either tuberculosis or lung cancer). Bronchitis is another cause of Dyspnoea. A recent visit to Asia increases the likelihood of tuberculosis, while smoking is a possible cause of both lung cancer and bronchitis" (Neapolitan, 1990, after Lauritzen and Spiegelhalter, 1988).

The Dyspnoea Example



A - Visit to Asia(a_1/a_2)
B - Tuberculosis(b_1/b_2)
C - Lung Cancer or Tuberculosis(c_1/c_2)
D - Positive X-Ray(d_1/d_2)
E - Lung Cancer(e_1/e_2)
F - Person Smokes(f_1/f_2)
G - Bronchitis(g_1/g_2)
H - Dyspnoea(h_1/h_2)

UAI at USC

1. The Decision Analysis Group (DAG):

   - John Rose
   - Marco Valtorta
   - Juan Vargas
   - `www.cse.sc.edu/research/dag`

2. Some Interested People in the Statistics Department: Jim Lynch, Steve Durham, Todd Ogden.

3. Other CSE Faculty with an Interest in UAI: John Bowles, Duncan Buell, Caroline Eastman, Manton Matthews.

Theses and Dissertations in UAI at USC

The table below lists only research directly relevant to Bayesian networks and directed by Drs. Rose, Valtorta, or Vargas. The papers counted are those directly related to student work and coauthored (at least) by a student. Additional work was carried out, for example, on the Dempster-Shafer theory of evidence.

	MS	PhD	Publications
John Rose	2	1	0
Marco Valtorta	11	1	8
Juan Vargas	4	1	4

Dissertations in UAI at USC

1. Clifton Presser (Rose). "Dynamic Goal Reassessment: Planning and Replanning in Uncertain Environments." PhD, 2000.

2. Miguel A. Barrientos (Vargas). "Dynamical Analysis of Temporal Processes Using Bayesian Belief Networks." PhD (Electrical and Computer Engineering), 1999.

3. Mark Bloemeke (Valtorta). "Agent Encapsulated Bayesian Networks." PhD, August 1998.

Dissertations in UAI at USC—Publications

1. Barrientos, Miguel A. and J.E. Vargas. "A Framework for Analysis of Dynamic Processes based on Bayesian Networks and Case-based Reasoning." World Congress on Expert Systems, March 1998.

2. Barrientos, Miguel A. and J.E. Vargas. "Analysis of time-varying processes based on Bayesian networks and case-based reasoning." International Workshop on Advanced Black-Box Techniques for Non-Linear Modeling, Leuven, Belgium, July 8-10, 1998.

3. Barrientos, Miguel A. and J.E. Vargas. "Predicting Air Quality Using Dynamic Bayesian Networks (Invited Contribution)." *International Journal of Expert Systems with Applications*, Permagon Press, July 1998.

4. Bloemeke, Mark and M. Valtorta. "A Hybrid Algorithm to Compute Marginal and Joint Beliefs in Bayesian Networks and Its Complexity." In: G.F. Cooper and S. Moral (eds.), *Uncertainty in Artificial Intelligence: Proceedings of the Fourteenth Conference.* San Francisco, CA: Morgan-Kaufmann, 1998, 16-23.

Theses: Learning

1. Bhaskara R. Moole (Valtorta). "Parallel Construction of Bayesian Belief Networks." MS(R), September 1997. (This thesis is referenced in: Pearl, Judea. *Causality.* Cambridge University Press, 2000.)

2. Moninder Singh (Valtorta). "Construction of Bayesian Network Structures from Data," MS(R), May 1993.

3. Randy Mechling (Valtorta). "PaCCIN: A Parallel Constructor of Causal Independence Networks," MS(R), July 1992.

Theses: Learning—Publications

1. Singh, Moninder and M. Valtorta. "Construction of Bayesian Belief Networks from Data: a Brief Survey and an Efficient Algorithm." *International Journal of Approximate Reasoning,* 12, 2 (February 1995), 111-131.

2. Singh, Moninder and M. Valtorta. "An Algorithm for the Construction of Bayesian Network Structures from Data." In: D. Heckerman and E.H. Mamdani (eds.), *Uncertainty in Artificial Intelligence: Proceedings of the Eighth Conference.* San Francisco, CA: Morgan-Kauffman, 1993, 259-265 (Winner of Student Paper Award).

3. Mechling, Randy and M. Valtorta. "A Parallel Constructor of Markov Networks." Pages 255-262 in: Cheeseman, Peter and Wayne Oldford (eds.): *Selecting Models from Data: Artificial Intelligence and Statistics IV*. Volume 89 of Lecture Notes in Statistics. New York: Springer-Verlag, 1994 (ISBN 0-387-94281-5).

Theses: Systems Issues

1. Chuong Duc Huyn (Valtorta). "Implementation of the Valuation-Based System for Bayesian Decision Analysis." MS(P), March 1999.

2. Jian-Rong Shi (Valtorta). "Sensitivity to Parameter and Evidence Values in Bayesian Networks." MS(P), November 1997.

3. Gopalakrishnan Viswanath (Valtorta). "A Survey and Comparison of Algorithms for the Compilation of Bayesian Networks." MS(R), November 1996.

4. Anapurna Gandikota (Vargas). "Design of an Object-Oriented Graphical User Interface for a Bayesian Belief Shell." (MS, Electrical and Computer Engineering), May 1996.

5. Kangesh Gunaseelan (Vargas). "Design and Implementation of an Object-oriented, Windows-based Interface for Integrating Databases with Bayesian Belief Networks." MS (Electrical and Computer Engineering), May 1996.

6. Ming Wu (Valtorta). "Design and Implementation of a Bayesian Belief Network with Graphical User Interface." MS(P), January 1995.

Theses: Applications in Medicine

1. Jayanta Ghosh (Valtorta). "A Probabilistic Model of Health and Nutrition of Elderly in South Carolina." MS(P), November 1999.

2. Adina Bica (Vargas). "Predicting the Outcome of Traumatic Head Injuries Using Bayesian Methods." MS (Electrical and Computer Engineering), April 1997.

3. Daniel Gage (Rose). "A Comparative Analysis of Bayesian Belief Networks and Classical Statistical Approaches." MS(R), 1995.

4. Subramani Mani (Valtorta). "MENTOR: A Bayesian Model for Prediction and Intervention in Mental Retardation." MS(P), August 1994.

Theses: Applications in Medicine—Publications

1. Jayanta Ghosh and M. Valtorta. "Building a Probabilistic Model of Heart Disease (Extended Abstract)." *Proceeding of the 38th Annual Southeastern ACM Conference,* Clemson, April 7-8, 2000, pp.239-240.

2. Bica, Adina C., A.W. Selassie, J.E. Vargas and E.P. McCutcheon. "Prediction of Outcome of Traumatic Brian Injuries Using Bayesian Belief Networks. *Prevention (Proceedings of the Conference of American College of Preventive Medicine and the Association of Teachers of Preventive Medicine)*, Atlanta GA., March 20-23, 1997.

3. Mani, Subramani, Suzanne McDermott, and Marco Valtorta. "A Bayesian Model for the Prediction of Mental Retardation in Newborns (Abstract)." *Prevention (Proceedings of the Conference of American College of Preventive Medicine and the Association of Teachers of Preventive Medicine)*, Atlanta GA., March 20-23, 1997.

4. Mani, Subramani, Suzanne McDermott, and Marco Valtorta. "MENTOR: A Bayesian Model for Prediction of Mental Retardation in Newborns." *Research in Developmental Disabilities*, 18 (1997), 5, pp.303-318.

Theses: Applications in Chemistry

Sonia Escudero (Rose). "A Bayesian Model for Reaction Classification." MS(R), 1995.

Theses: Applications in Finance

Leszek Piatkiewicz (Valtorta). "On the Construction of a Bayesian Network for Agricultural Loan Assessment." MS(R), March 1996.

Theses: Integration with Case-Based Reasoning

Amal Shah (Vargas). "Design of a Bayesian Retriever for Case Based Reasoning." MS (Electrical and Computer Engineering), January 1995.

Theses: Abstraction and Conflict Detection

Young-Gyun Kim (Valtorta). “Design and Construction of a New Straw Model in Bayesian Networks.” MS(R), November 1994.

Theses: Abstraction and Conflict Detection—Publication

Kim, Young-Gyun and M. Valtorta. "On the Detection of Conflicts in Diagnostic Bayesian Networks Using Abstraction." In: Ph. Besnard and S. Hanks (eds.), *Uncertainty in Artificial Intelligence: Proceedings of the Eleventh Conference.* San Francisco, CA: Morgan-Kaufmann, 1995, 362-367.

Theses: Other Numerical Techniques for Handling Uncertainty

These are not counted in the summary tables and are provided only for illustrative purposes.

1. Dahai Zang (Valtorta). "An Analysis of Rule-Strength Refinement Algorithms for Expert Systems." MS(R), July 1990.

2. Shijie Wang (Valtorta). "BELFUN–A Belief Function Expert System Shell." MS(R), November 1990.

Theses: Other Numerical Techniques for Handling Uncertainty—Publications

1. Wang, Shijie and M. Valtorta. "On The Exponential Growth Rate of Dempster-Shafer Belief Functions." *Proceedings of the SPIE Conference on Applications of Artificial Intelligence X: Knowledge-Based Systems*, 15-24, Orlando, FL, April 1992.

2. Wang, Shijie and M. Valtorta. "On the Conversion of Rule Bases into Belief Networks." *Proceedings of the 1992 ACM/SIGAPP Symposium on Applied Computing*, 363-368, Kansas City, MO, March 1992.

Thesis Topic: Comparison of Existing Shells for Bayesian Networks and Influence Diagrams

This is an M.S. (P) thesis topic. It may also be a good topic for an honors thesis.

The student would design a set of evaluation criteria (covering, e.g., user interface issues, functionality, and efficiency) to compare existing shells and evaluate, at least, the ones that are available for academic use free of charge, including Hugin Light (`www.hugin.dk`), MSBN (`research.microsoft.com/dtas/msbn`), GeNie (`www2.sis.pitt.edu/~genie`), Netica (`www.norsys.com`), and WEBWEAR-III (`cs.uregina.ca/~yxiang/ww3`). Evaluation will include some experimentation, for example tied to a 500-level course.

Thesis Topic: CB, Revisited

This is an M.S. (P) thesis topic.

The student would implement the Bayesian network learning algorithm CB with a polished user interface. The implementation would be sufficiently robust and efficient for use by non-specialists and sufficiently modular and well documented to be extended and integrated with other Bayesian network software tools.

Thesis Topic: SQL Implementation of the Junction Tree Method for Probability Update in Bayesian Networks

This is an M.S. (P) thesis topic.

The student would implement the Junction Tree Method in SQL. This work would be based on algorithms by Wong, Butz, and Xiang, as published in the UAI-95 proceedings. The implementation would run on the NCR Teradata computer recently acquired by Professors Huhns and Vargas for USC. The implementation would be sufficiently robust and efficient for use by non-specialists and sufficiently modular and well documented to be extended and integrated with other Bayesian network software tools.

Thesis Topic: The Factor Tree Method for Probability Update in Bayesian Networks

This is an M.S. (P or R) thesis topic. It may grow into a Ph.D. topic.

The student would implement the factor tree method of Bloemeke (Bloemeke and Valtorta, UAI-98) and some of its variants. Time and space efficiency would be more important than usability, extensibility, and integrability. Experiments would be run to compare the efficiency of probability update using factor trees to other exact methods (e.g, junction trees, SPI).

Thesis Topic: Learning Bayesian Networks from Relational Databases

This is an M.S. (R) topic. It may grow into a Ph.D. topic.

The student would study how to exploit the structure of relational databases for Bayesian network learning, propose algorithms to carry out this task, study their complexity, and carry out a research-style implementation. (A starting point may be Friedman, Getoor, Koller, and Pfeffer's "Learning Probabilistic Relational Models," IJCAI-99.)

Thesis Topic: Beginnings of a Causal Modeler's Workbench

This is an M.S. (P) thesis topic. It may grow into a Ph.D. topic.

The student would implement a basic shell for causal Bayesian networks, supporting the criteria for identifiability, such as the back door criterion, as described by Pearl (*Biometrika*, 1995; *Causality*, Chapter 3, 2000), and extending the C implementation of the back door criterion by Woody Folsom. The shell would include a polished user interface. The implementation would be sufficiently robust and efficient for use by non-specialists and sufficiently modular and well documented to be extended and integrated with other Bayesian network software tools.

Thesis Topic: Soft Evidential Update

This is an M.S. (P) thesis topic. It may grow into a Ph.D. topic.

The student would implement the two algorithms for soft evidential update by Valtorta, Vomlel and Kim (2000, submitted). Time and space efficiency, usability, extensibility, and integrability would all be important criteria.

Thesis Topic: Evidence in Decision Networks

This is an M.S. (R) thesis topic. It may grow into a Ph.D. topic.

The student would explore the meaning of evidence, both hard and soft, in influence diagrams, design a modified version of the strong junction tree algorithm that correctly deals with influence, and implement the algorithm.

Some Suggestions for a Budding Researcher

1. Be a good scholar.
   (a) Scholarship is the foundation of research.
   (b) Surprise your advisor!
   (c) Attend colloquia.
2. Keep a lab book.
3. Visit your library often.
   (a) Read abstracts of journal articles.
   (b) Read journal articles.
   (c) Skim theory journals, such as *JACM*.
   (d) Copy abstracts or other quotes from articles into your lab book.

4. Follow the work of world-class researchers in your area.

    (a) Check their web pages.

    (b) Write requesting reprints.

    (c) E-mail (in moderation!) asking for clarifications.

5. If you can afford to, avoid the temptation to be "too damned relevant" (Wulf, *CRA News*, September 2000).

    (a) Good research should be beautiful and fun.

    (b) You will make money later.

6. Do not spend too much time in front of the computer screen.

7. Avoid all-nighters. Sleep and be sharp.