

PROBABILISTIC NETWORKS FOR AUTOMATED REASONING

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1 Findings and Contributions

This section describes the major findings of our research in a form of annotated list of the major publications. A complete list of publications is given in the appropriate sections.

Pearl, “Causal Inference in the Health Sciences: A Conceptual Introduction,” *Health Services and Outcomes Research Methodology*, special issue on causal inference, Vol. 2, 189–220, 2002.

The work discusses the paradigmatic shifts that must be undertaken in moving from traditional statistical analysis to causal analysis of multivariate data, with emphasis on the assumptions that underlie causal inferences, and the formal languages used in formulating those assumptions. nonexperimental studies. These emphases are illustrated through a survey of applications, including a symbiosis between counterfactual and graphical methods.

Pearl, J. “Comments on Seeing and Doing” *International Statistic Reviews*, 207–209, 2002.

This work discusses the mathematical foundations of causality and stresses the importance of mathematical notation for distinguishing causal from associational relationships.

Brito, C. and Pearl, J., "A New Identification Condition for Recursive Models with Correlated Errors," *Journal Structural Equation Modeling*, Vol. 9, No. 4, 459–474, 2002. This paper shows that identification is ensured as long as error correlation does not exist between a cause and its *direct* effect; no restrictions are imposed on errors associated with indirect causes. This criterion extends substantially our ability to determine the identification of causal models prior to conducting any data analysis.

Pearl, J., "Reasoning with cause and effect," *AI Magazine*, Vol. 23, No. 1, 95–111, Spring 2002.

This paper summarizes concepts, principles, and tools used in causal modeling. The principles are based on structural-model semantics, in which functional (or counterfactual) relationships, representing autonomous physical processes are the fundamental building blocks.

Brito, C. and Pearl, J., "A Graphical Criterion for the Identification of Causal Effects in Linear Models," *Proceedings of the Eighteenth National Conference on Artificial Intelligence*, AAAI Press/The MIT Press: Menlo Park, CA, 533–538, August 2002.

This paper concerns the assessment of direct causal effects from a combination of: (i) non-experimental data, and (ii) qualitative domain knowledge. Domain knowledge is encoded in the form of a directed acyclic graph (DAG), in which all interactions are assumed linear, and some variables are presumed to be unobserved. The paper establishes a sufficient criterion for the identifiability of all causal effects in such models as well as a procedure for estimating the causal effects from the observed covariance matrix.

Tian, J. and Pearl, J., "A New Characterization of the Experimental Implications of Causal Bayesian Networks," *Proceedings of the Eighteenth National Conference on Artificial Intelligence*, AAAI Press/The MIT Press: Menlo Park, CA, 574–579, August 2002.

The paper develops a complete characterization of the set of distributions that could be induced by local interventions on variables governed by a causal Bayesian network. We show that such distributions must

adhere to three norms of coherence, and we demonstrate the use of these norms as inferential tools in tasks of learning and identification.

Tian, J. and Pearl, J., “A General Identification Condition for Causal Effects,” *Proceedings of the Eighteenth National Conference on Artificial Intelligence*, AAAI Press/The MIT Press: Menlo Park, CA, 567–573, August 2002.

This work concerns the assessment of the effects of actions or policy interventions from a combination of: (i) nonexperimental data, and (ii) substantive assumptions encoded in a graph. The paper establishes a necessary and sufficient criterion for the identifiability of the causal effects of a singleton variable on all other variables in the model, and a powerful sufficient criterion for the effects of a singleton variable on any set of variables.

Brito, C. and Pearl, J., “Generalized Instrumental Variables,” In A. Darwiche and N. Friedman (Eds.), *Uncertainty in Artificial Intelligence, Proceedings of the Eighteenth Conference*, Morgan Kaufmann: San Francisco, CA, 85–93, August 2002. UAI-02 Best Paper Award.

This paper develops techniques for the assessment of direct causal effects in in feedback-less systems where all interactions are assumed linear and some variables are presumed to be unobserved. The techniques developed are shown to be more powerful than any known method.

Bonet, B. and Pearl, J., “Qualitative MDPs and POMDPs: An Order-of-Magnitude Approximation,” In A. Darwiche and N. Friedman (Eds.), *Uncertainty in Artificial Intelligence, Proceedings of the Eighteenth Conference*, Morgan Kaufmann: San Francisco, CA, 61–68, August 2002.

The paper develops a qualitative theory of Markov Decision Processes (MDPs) and Partially Observable MDPs that can be used to model sequential decision making tasks when only qualitative information is available. The approach, based upon an order-of-magnitude approximation of both probabilities and utilities, enables the use of deterministic planning techniques in problems involving uncertainty.

Tian, J. and Pearl, J., “On the Testable Implications of Causal Models with Hidden Variables,” In A. Darwiche and N. Friedman (Eds.), *Un-*

certainty in Artificial Intelligence, Proceedings of the Eighteenth Conference, Morgan Kaufmann: San Francisco, CA, 519–527, August 2002.

This paper offers a systematic way of identifying the functional constraints induced by causal models with unmeasured variables. These constraints provide the only means of testing such models.

Hopkins, M. and Pearl, J., “Causality and Counterfactuals in the Situation Calculus,” UCLA Computer Science Department, Technical Report (R-301), January 2002. This paper formulates an effective theory of counterfactuals within the situation-calculus and, thus, leverage the power of the situation calculus to express complex, dynamically changing situations.

Hopkins, M., “Strategies for Determining Causes of Events,” *Proceedings of the Eighteenth National Conference on Artificial Intelligence*, AAAI Press/The MIT Press: Menlo Park, CA, 546–552, August 2002.

The paper develops two admissible pruning strategies for determining actual causes of events in specific scenarios.

2 A list of current team members (PIs, students, postdocs, etc).

Judea Pearl (PI)
Avin, Chen (Graduate Student)
Bonet, Blai (Graduate Student)
Brito, Carlos (Graduate Student)
Hopkins, Mark (Graduate Student)
Tian, Jin (PhD, 2002)
Azaria Paz (Visiting Professor, Technion, Israel)

Additional Publications

Pearl, “Causal Inference in the Health Sciences: A Conceptual Introduction,” *Health Services and Outcomes Research Methodology*, special is-

- sue on causal inference, Vol. 2, 189–220, Kluwer Academic Publishers, 2001.
- Pearl, J., “Reasoning with cause and effect,” *AI Magazine*, Vol. 23, No. 1, 95–111, Spring 2002.
- Pearl, J., “Comments on Seeing and Doing,” *International Statistic Reviews*. Vol. 70(2): 207–209, 2002.
“Comments on Nozer Singpurwalla’s ‘On Causality and Causal Mechanisms’,” *International Statistical Review*, Vol. 70(2): 210–212, 2002.
“A Short Rejoinder to Rejoinder,” Vol. 70(2): 214, 2002.
- Tian, J. and Pearl, J., “A General Identification Condition for Causal Effects,” in *Proceedings of the Eighteenth National Conference on Artificial Intelligence*, AAAI Press/The MIT Press: Menlo Park, CA, 567–573, August 2002.
- Brito, C. and Pearl, J., “A New Identification Condition for Recursive Models with Correlated Errors,” *Journal Structural Equation Modeling*, Vol. 9, No. 4, 459–474, 2002.
- Brito, C. and Pearl, J., “A Graphical Criterion for the Identification of Causal Effects in Linear Models,” in *Proceedings of the Eighteenth National Conference on Artificial Intelligence*, AAAI Press/The MIT Press: Menlo Park, CA, 533–538, August 2002.
- Tian, J. and Pearl, J., “A New Characterization of the Experimental Implications of Causal Bayesian Networks,” in *Proceedings of the Eighteenth National Conference on Artificial Intelligence*, AAAI Press/The MIT Press: Menlo Park, CA, 574–579, August 2002.
- Hopkins, M., “Strategies for Determining Causes of Events,” in *Proceedings of the Eighteenth National Conference on Artificial Intelligence*, AAAI Press/The MIT Press: Menlo Park, CA, 546–552, August 2002.
- Brito, C. and Pearl, J., “Generalized Instrumental Variables,” In A. Darwiche and N. Friedman (Eds.), *Uncertainty in Artificial Intelligence, Proceedings of the Eighteenth Conference*, Morgan Kaufmann: San Francisco, CA, 85–93, August 2002. UAI-02 Best Paper Award,

Bonet, B. and Pearl, J., “Qualitative MDPs and POMDPs: An Order-of-Magnitude Approximation,” In A. Darwiche and N. Friedman (Eds.), *Uncertainty in Artificial Intelligence, Proceedings of the Eighteenth Conference*, Morgan Kaufmann: San Francisco, CA, 61–68, August 2002.

Tian, J. and Pearl, J., “On the Testable Implications of Causal Models with Hidden Variables,” In A. Darwiche and N. Friedman (Eds.), *Uncertainty in Artificial Intelligence, Proceedings of the Eighteenth Conference*, Morgan Kaufmann: San Francisco, CA, 519–527, August 2002.

Tian, J. “Studies in Causal Reasoning and Learning,” UCLA Computer Science Department, Ph.D. Thesis, Technical Report (R-309), August 2002.

Pearl, J. & Russell, S., “Bayesian Networks,” UCLA Computer Science Department, Technical Report (R-277), In M. Arbib (Ed.), *Handbook of Brain Theory and Neural Networks*, Second edition, 157–160, Cambridge, MA: MIT Press, 2003.

AWARDS

J. Pearl’s book, *Causality: Models, Reasoning and Inference*, has won the Lakatos Award for 2001. The Lakatos is awarded each year by the London School of Economics for the most outstanding contribution to the philosophy of science.

B. Bonet’s paper “Instrumentality Tests Revisited” was selected as a “Best-student paper award runner-up” at the Seventeenth Conference on Uncertainty in Artificial Intelligence, UAI-01, Seattle, August 2001.

C. Brito and J. Pearl’s paper “Generalized Instrumental Variables,” was received the “Best Paper Award,” at the Eighteenth Conference on Uncertainty in Artificial Intelligence, UAI-02, Canada, August 2002.