# RESEARCH SUMMARY

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This summary outlines a research program which over the past seven years has been oriented towards developing new methodologies to solve challenging engineering problems. The emphasis is on the integration of qualitative and quantitative reasoning. As our work in diagnostics, monitoring and and control depends on first principle models of the underlying designs, we have also included a brief summary of research in these fields as well.

## Mechanical Design

- Qualitative Reasoning from First Principles
  - SYmbolic MONotonicity analyzer (SYMON)
  - SYMmbolic FUNctional Evaluator (SYMFUNE)
  - 1*PRINCE (First PRINciple Computational Evaluator)
  - Monotonic Influence Diagrams (MIDs)
- Object-oriented data structures for reasoning about functionality, manufacturability and diagnosability (knowledge representations for mechanical systems)
- Interactive multiobjective optimization algorithms
- Expert systems applied to rehabilitative engineering
- Graphics and CAD/CAM - Design by features
- Expert interrogators for preference assessment
- Decision / design process management for life cycle design

## Diagnostics,Monitoring and Intelligent Supervisory Control

- **IDES** - **I**nfluence **D**iagram Based **E**xpert **S**ystem
  - Allows three hierarchical levels of specification: symbolic, functional, and numerical
  - Makes use of multivariate logic (e.g., probability and fuzzy logic)
  - Efficient symbolic algorithms that makes real-time diagnostic applications feasible
- Reasoning by analogy and machine learning
- Qualitative reasoning in mechanical failure prediction by audible sound
- Integration with adaptive neural networks
- Integration with AI/Expert system environments
- Architectures for sensor fusion and sensor validation
- Real-time diagnostic decision making for process control
- Applications to machining operations (milling and drilling), assembly line testing, electric power generation, and the space vehicles.

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## Selected Relevant Publications


Choy, J.K. and A.M. Agogino, "SYMON: Automated Symbolic Monotonicity Analysis System for Qualitative Design Optimization," *Proceedings of the 1986 International Computers in Engineering Conference,* ASME, Vol. 2, 1986, pp. 305-310.

Moore, E.A. and A.M. Agogino, "INFORM: An Architecture for Expert-Directed Knowledge Acquisition," *International Journal of Man-Machine Studies,* Vol. 26, No. 2, February 1987, pp. 213-230.

Rege, A. and A.M. Agogino, "Topological Framework for Representing and Solving Probabilistic Inference Problems in Expert Systems," *IEEE Systems, Man, and Cybernetics,* Vol. 18 (3), May/June 1988 , pp. 402-414.

Michelena, N. and A.M. Agogino, "Multiobjective Hydraulic Cylinder Design," *ASME Journal of Mechanisms, Transmissions, and Automation in Design,* Vol. 110, March 1988, pp. 81-87.

Agogino, A.M., "AI in Computer-Aided Design: Qualitative Reasoning and Symbolic Computation," *The Study of the Design Process,* ed. M. Waldron, 1987, pp. 263-294.

Agogino, A.M. and A. Almgren, "Techniques for Integrating Qualitative Reasoning and Symbolic Computation in Engineering Optimization," *Engineering Optimization,* Vol. 12(2), Sept./Oct. 1987, pp. 117-135.

Almgren, A. and A.M. Agogino, "A Generalization and Correction of the Welded Beam Optimal Design Problem Using Symbolic Computation," *ASME Journal of Mechanisms, Transmissions, and Automation in Design,* Vol. 111 (1), March 1989, pp. 137-140.

Cagan, J. and A.M. Agogino, "Innovative Design of Mechanical Structures from First Principles," *AI in Engineering, Design, Analysis, and Manufacturing,* Vol. 1 (3), 1987, pp. 169-189.

Agogino, A.M., O. Nour-Omid, W. Imaino and S.S. Wang, "Decision-Analytic Methodology for Cost-Benefit Evaluation of Diagnostic Testers," *Transactions of the IIE,* Vol. 24, No. 1, March 1992.

Agogino, A.M., S. Srinivas and K. Schneider, "Multiple Sensor Expert System for Diagnostic Reasoning, Monitoring, and Control of Mechanical Systems," *Mechanical Systems and Signal Processing,* Vol. 2(2), 1988, pp. 165-185.

Agogino, A.M and K. Ramamurthi, "Real Time Influence Diagrams for Monitoring and Controlling Mechanical Systems,"*Influence Diagrams, Belief Nets and Decision Analysis* (ed., R.M. Oliver and J.Q. Smith), John Wiley & Sons, 1990, Chap. 9, pp. 199-228.

Agogino, A.M., S.R. Bradley, J. Cagan, P. Jain, and N. Michelena, "AI/OR Computational Model for Integrating Qualitative and Quantitative Design Methods," *Proceedings of the NSF Engineering Design Research Conference* (Amherst, MA, June 1989), pp. 97-112.

Nadi, Fariborz, A.M. Agogino, and D. Hodges, "Use of Influence Diagrams and Neural Networks in Modeling Semiconductor Manufacturing Processes," *IEEE Transactions on Semiconductor Manufacturing,* Vol. 4, No. 1, Feb. 1991, pp. 52-58.

Cagan, J. and A.M. Agogino, "Inducing Constraint Activity in Innovative Design", *AIEDAM* (AI in Engineering Design, Automation, and Manufacturing), Vol. 5, No. 1, pp. 47-61.

Bradley, S.R. and A.M. Agogino, "Design Capture and Information Management for Concurrent Design," *International Journal of Systems Automation: Research & Applications,* Vol. 1, No. 2., pp. 117-141.

Cagan, J. and A.M. Agogino, "Dimensional Variable Expansion - A Formal Approach to Innovative Design," *Research in Engineering Design.,* Vol. 3, No. 2, 1991, pp. 75-85.

Michelena, N. and A.M. Agogino, "Formal Solution of N-type Taguchi Parameter Design Problems with Stochastic Noise Factors," *ASME '91 Design Theory and Methods,* ASME DE-Vol. 31, 1991, pp. 13-20.

Michelena, N. and A.M. Agogino, "Monotonic Influence Diagrams: Foundations and Application to Optimal Design," Working Paper #F 91-1101-0.

Michelena, N. and A.M. Agogino, "Monotonic Influence Diagrams: Extension to Stochastic Programming and Application to Probabilistic Design," Working Paper # 91-1102-0.

Osborn, J.R. and A.M. Agogino, "An Interface for Interactive Spatial Reasoning and Visualization," *CHI'92 Proceedings* (Conference on Human Factors in Computing Systems ),May 1992.