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13. ABSTRACT (Maximum 200 words) The motivating application for this research is the global/local optimal design of composite aircraft structures such as wings and fuselages, but the theory and algorithms are more widely applicable in engineering design. Research is proposed on three distinct topics. (1) Rigorous mathematical theory will be developed supporting a decomposition strategy for global/local optimization. Advanced computational and numerical approximation techniques, such as massively parallel computing and surrogate functions, will be used in the decomposition. (2) Local panel optimization algorithms that can handle both discrete and continuous variables efficiently will be investigated. Several different strategies for blending local composite panel designs to improve manufacture will be developed and tested. (3) Mathematical theory and parallel computing paradigms for cellular automata applied to structural design will be developed and validated on a variety of structural design problems. Comparison to standard FEM-based optimization will be done.				
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FINAL REPORT FOR AFOSR GRANT F49620-02-1-0090

**THEORY AND ALGORITHMS FOR GLOBAL/LOCAL
DESIGN OPTIMIZATION**

Period: 01/01/2002 — 09/30/2005

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Objectives.

The motivating application for this research is the global/local optimal design of composite aircraft structures such as wings and fuselages, but the theory and algorithms are more widely applicable in engineering design. Research is proposed on three distinct topics. (1) Rigorous mathematical theory will be developed supporting a decomposition strategy for global/local optimization. Advanced computational and numerical approximation techniques, such as massively parallel computing and surrogate functions, will be used in the decomposition. (2) Local panel optimization algorithms that can handle both discrete and continuous variables efficiently will be investigated. Several different strategies for blending local composite panel designs to improve manufacture will be developed and tested. (3) Mathematical theory and parallel computing paradigms for cellular automata applied to structural design will be developed and validated on a variety of structural design problems. Comparison to standard FEM-based optimization will be done.

Major accomplishments.

Significant progress was made on each of the three research objectives. (1) Haftka and Watson developed a rigorous decomposition theory for a large class of multidisciplinary design optimization problems involving both real and integer variables, and demonstrated the utility of the theory for parallel optimization and large scale engineering design. (2) Significant new genetic algorithms employing memory, migration, new mixed integer variable encodings, and new local improvement schemes were developed and applied to blended composite panel wing design. (3) The suitability of cellular automata for massively parallel structural design was explored in depth, with both theoretical and applied results obtained.

The project produced two Ph.D. theses, two M.S. theses, and partially supported numerous students and visiting faculty besides the PIs. Directly or indirectly attributable to the grant support are over 45 journal publications, over 60 refereed conference papers, and over 20 articles currently under review. Substantial technology transition to industry and government also occurred during the grant period.

Personnel supported.

Faculty supported by the grant are Z. Gürdal, R. T. Haftka, and L. T. Watson. Graduate students supported by the grant are David Adams and Vladimir Gantovnik at Virginia Tech, and Laurent Grosset and Jaco Schutte at Florida. Others associated with the project are students Shahriar Setoodeh, Omprakash Seresta, Ozlem Armutcuoglu, Mostafa Abdalla, Douglas Slotta, and Manjula Iyer, post-docs Boyang Liu and Samy Missoum, and a Statistics Department faculty member Christine Anderson-Cook.

Publications.

Journal articles published during the grant period are:

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- S. Hosder, B. Grossman, R. T. Haftka, W. H. Mason, and L. T. Watson, "Quantitative relative comparison of CFD simulation uncertainties for a transonic diffuser problem", *Comput. & Fluids*, to appear.
- S. Setoodeh, D. B. Adams, Z. Gürdal, and L. T. Watson, "Pipeline implementation of cellular automata for structural design on message-passing multiprocessors", *Math. Comput. Modeling*, to appear.
- R. T. Haftka and L. T. Watson, "Decomposition theory for multidisciplinary design optimization problems with mixed integer quasiseparable subsystems", *Optim. Engrg.*, to appear.
- V. M. Pérez, J. E. Renaud, and L. T. Watson, "Homotopy curve tracking in approximate interior point optimization", *Optim. Engrg.*, to appear.
- S. Setoodeh, Z. Gürdal, and L. T. Watson, "Design of variable-stiffness composite layers using cellular automata", *Comput. Methods Appl. Mech. Engrg.*, to appear.
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- A. Verstak, N. Ramakrishnan, K. K. Bae, W. H. Tranter, L. T. Watson, J. He, C. A. Shaffer, and T. S. Rappaport, "Using hierarchical data mining to characterize performance of wireless system configurations", *ACM Trans. Modeling Comput. Simulation*.
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- M. A. Gonçalves, E. A. Fox, L. T. Watson, and N. A. Kipp, "Towards a digital library theory: a formal digital library ontology", *Internat. J. Digital Libraries*.

Interactions/transitions.

Conference presentations were:

- NSF Design, Service, and Manufacturing Grantees and Research Conference, San Juan, PR, Jan., 2002.
- Numerical Aspects of Circuit and Device Modeling Workshop, Santa Fe, NM, April, 2002.
- International Parallel and Distributed Processing Symposium 2002, Fort Lauderdale, FL, April, 2002 (2 papers).
- High Performance Computing Symposium 2002, San Diego, CA, April, 2002 (2 papers).
- AIAA/ASME/ASCE/AHS/ASC 43rd Structures, Structural Dynamics, and Materials Conference, Denver, CO, April, 2002 (7 papers).

SIAM Conference on Optimization, Toronto, Canada, May, 2002 (3 papers).

IEEE 2002 Radio and Wireless Conference, Boston, MA, August, 2002.

Electronic Prototyping Review Meeting, Sunnyvale, CA, July, 2002.

9th AIAA/ISSMO Symp. on Multidisciplinary Analysis and Optimization, Atlanta, GA, Sept., 2002 (7 papers).

IEEE Vehicular Technology Fall Conference, Vancouver, Canada, Sept., 2002.

Sixth European Panel Products Symposium, Llandudno, Wales, United Kingdom, Oct., 2002.

International Academy of Wood Science Annual Meeting, Beijing, China, Oct., 2002.

OSB World Symposium and Exposition, Chicago, IL, Oct., 2002.

3rd International Conference on Systems Biology, Stockholm, Sweden, Dec., 2002.

SIAM Conference on Computational Science and Engineering, San Diego, CA, Feb., 2003.

High Performance Computing Symposium 2003, Orlando, FL, March, 2003 (2 papers).

AIAA/ASME/ASCE/AHS 44th Structures, Structural Dynamics, and Materials Conf., Norfolk, VA, April, 2003 (6 papers).

17th International Parallel and Distributed Processing Symposium, Nice, France, April, 2003.

Spring Research Conference on Statistics in Industry and Technology, Dayton, OH, June, 2003.

Summer Bioengineering Conference, Key Biscayne, Florida, June 2003 (2 papers).

2003 ASME International Mechanical Engineering Congress, Washington, D.C., 2003.

29th Annual Conference of the IEEE Industrial Electronics Society, Roanoke, VA, 2003.

6th CanSmart Workshop on Smart Materials and Structures, Montreal, Quebec, Canada, 2003.

American Soc. for Composites 18th Technical Conf., Gainesville, FL, October, 2003.

6th Internat. Conf. on Artificial Evolution, Marseille, France, October, 2003.

2003 Winter Simulation Conference, New Orleans, LA, Dec., 2003.

11th SIAM Conference on Parallel Processing for Scientific Computing, San Francisco, CA, Feb., 2004.

AIAA/ASME/ASCE/AHS/ASC 45th Structures, Structural Dynamics, and Materials Conf., Palm Springs, CA, April, 2004 (5 papers).

High Performance Computing Symposium 2004, Arlington, VA, April, 2004.

International Parallel and Distributed Processing Symposium 2004, Santa Fe, NM, April, 2004.

Numerical Aspects of Circuit and Device Modeling Workshop, Santa Fe, NM, June, 2004.

Forest Products Society 58th Annual Meeting, Grand Rapids, MI, June, 2004.

AFOSR Workshop and Contractors' Meeting, Pasadena, CA, August, 2004.

10th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, Albany, NY, August, 2004 (6 papers).

26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, San Francisco, CA, Sept., 2004.

SPIE 11th Annual International Symposium on Smart Structures and Materials: Modeling, Signal Processing, and Control, San Diego, CA, 2004.

Spring Simulation Multiconference, San Diego, CA, April, 2005 (3 papers).

SIAM Annual Meeting, New Orleans, LA, July, 2005.

International Conference on Complementarity, Duality, and Global Optimization in Science and Engineering, Blacksburg, VA, August, 2005.

American Society for Photogrammetry and Remote Sensing 16th Pecora Symposium, Sioux Falls, SD, Oct., 2005.

Technology transitions or transfer:

PERFORMER

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CUSTOMER

General Motors Research and Development Center
Warren, MI

Contact: Alexander P. Morgan, 810-986-2157

RESULT

Homotopy algorithms; mathematical software

APPLICATION

Linkage mechanism design; combustion chemistry; robotics; CAD/CAM

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Lucent Technologies
Murray Hill, NJ

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RESULT

Homotopy algorithms; mathematical software

APPLICATION

Circuit design and modelling

PERFORMER

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CUSTOMER

Michelin Americas
Greenville, SC

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RESULT

Adaptive GMRES algorithm; mathematical software

APPLICATION

Iterative solution of large linear systems arising from tire modelling

PERFORMER

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CUSTOMER

Visteon, Inc.
Dearborn, MI 48126

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RESULT

Probability based genetic algorithms

APPLICATION

Design of composite automotive structures

PERFORMER

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CUSTOMER

Boeing

Seattle, WA

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RESULT

Bilevel optimization

APPLICATION

Design of aircraft

PERFORMER

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CUSTOMER

Sikorsky Aircraft

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RESULT

Genetic algorithms for composite laminate design

APPLICATION

Design of helicopter frame structures for minimum weight and cost

PERFORMER

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CUSTOMER

ADOPTech Inc.

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RESULT

Blending algorithm for multipanel composite structural design

APPLICATION

Design of helicopter skin structures for minimum weight and cost

PERFORMER

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CUSTOMER

Ford Research Laboratory, Vehicle Safety Research Department

Detroit, Michigan 48121

Contact: Dr. Ren-Jye Yang, 313-845-5916

RESULT

Displacement based optimization for structures with nonlinear response

APPLICATION

Minimum weight design of automotive structures for crashworthiness