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.
FINAL REPORT FOR AFOSR GRANT F49620-02-1-0090

THEORY AND ALGORITHMS FOR GLOBAL/LOCAL
DESIGN OPTIMIZATION

Period: 01/01/2002 — 09/30/2005

Layne T. Watson
Departments of Computer Science and Mathematics – 0106
Virginia Polytechnic Institute & State University
Blacksburg, VA 24061
ltw@cs.vt.edu

Zafer Gürdal
Departments of Aerospace and Ocean Engineering,
and Engineering Science and Mechanics – 0219
Virginia Polytechnic Institute & State University
Blacksburg, VA 24061
zgurdal@vt.edu

in collaboration with

Raphael T. Haftka
Department of Mechanical and Aerospace Engineering
University of Florida
Gainesville, FL 32611-6250
haftka@ufl.edu

September 29, 2005

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

20051110 031
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:


Refereed conference papers published during the grant period are:


Journal articles accepted during the grant period are:


Journal articles submitted during the grant period are:


Interactions/transitions.

Conference presentations were:


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).


SIAM Conference on Optimization, Toronto, Canada, May, 2002 (3 papers).
Sixth European Panel Products Symposium, Llandudno, Wales, United Kingdom, Oct., 2002.
17th International Parallel and Distributed Processing Symposium, Nice, France, April, 2003.
Summer Bioengineering Conference, Key Biscayne, Florida, June 2003 (2 papers).
6th CanSmart Workshop on Smart Materials and Structures, Montreal, Quebec, Canada, 2003.
6th Internat. Conf. on Artificial Evolution, Marseille, France, October, 2003.
International Parallel and Distributed Processing Symposium 2004, Santa Fe, NM, April, 2004.
Spring Simulation Multiconference, San Diego, CA, April, 2005 (3 papers).
Technology transitions or transfer:

PERFORMER
Layne T. Watson, Virginia Polytechnic Institute & State University
Telephone: 540-231-7540
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

PERFORMER
Layne T. Watson, Virginia Polytechnic Institute & State University
Telephone: 540-231-7540
CUSTOMER
Lucent Technologies
Murray Hill, NJ
Contact: Robert Melville, 908-582-2420
RESULT
Homotopy algorithms; mathematical software
APPLICATION
Circuit design and modelling

PERFORMER
Layne T. Watson, Virginia Polytechnic Institute & State University
Telephone: 540-231-7540
CUSTOMER
Michelin Americas
Greenville, SC
Contact: John Melson, 864-422-4246
RESULT
Adaptive GMRES algorithm; mathematical software
APPLICATION
Iterative solution of large linear systems arising from tire modelling

PERFORMER
Raphael T. Haftka, University of Florida
Telephone: 352-392-9595
CUSTOMER
Visteon, Inc.
Dearborn, MI 48126
Contact: Naveen Rastogi, 313-755-6264
RESULT
Probability based genetic algorithms
APPLICATION
Design of composite automotive structures
PERFORMER
Raphael T. Haftka, University of Florida
Telephone: 352-392-9595
CUSTOMER
Boeing
Seattle, WA
Contact: Cliff Chen
RESULT
Bilevel optimization
APPLICATION
Design of aircraft

PERFORMER
Zafer Gürdal, Virginia Polytechnic Institute & State University
Telephone: 540-231-5905
CUSTOMER
Sikorsky Aircraft
Stratford, Connecticut 06497
Contact: Christos Kassapoglou, 203-386-3292
RESULT
Genetic algorithms for composite laminate design
APPLICATION
Design of helicopter frame structures for minimum weight and cost

PERFORMER
Zafer Gürdal, Virginia Polytechnic Institute & State University
Telephone: 540-231-5905
CUSTOMER
ADOPTech Inc.
Blacksburg, VA 24061
Contact: Grant Soremekun, 540-231-7232
RESULT
Blending algorithm for multipanel composite structural design
APPLICATION
Design of helicopter skin structures for minimum weight and cost

PERFORMER
Zafer Gürdal, Virginia Polytechnic Institute & State University
Telephone: 540-231-5905
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