CONTINUATION AND MULTI-GRID FOR BIFURCATION PROBLEMS

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In the following we give an overview of the work completed under grant AFOSR-90-0080 since December 1989. The research concerned the numerical solution of bifurcation and nonlinear eigenvalue problems for parameter-dependent partial differential equations and systems. The scope of the research is rather wide, stressing the development, study and implementation of computational methods for several classes of difficult nonlinear problems of difficult nonlinear problems, but, also including the derivation of analytic results in cases where these questions had not been settled before.

This grant was a continuation and extension of grant AFOSR-84-315. The earlier grant has resulted in 26 papers over a 5-year period. The present grant resulted in the publication of 18 papers in refereed journals or refereed high-quality proceedings volumes and of one book. Several of the 26 papers generated under the earlier grant were listed as to appear in the final report for that grant. They all have appeared but are not listed here again. Instead, for simplicity, we refer to the papers and books produced under the

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Continuation and Multi-grid Methods
for
Bifurcation Problems

Duration of Grant: December 1, 1989 – August 15, 1993

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1. Accomplishments under the Grant

In the following we give an overview of the work completed under grant AFOSR-90-0080 since December 1, 1989. The research concerned the numerical solution of bifurcation and nonlinear eigenvalue problems for parameter-dependent partial differential equations and systems. The scope of the research is rather wide, stressing the development, study, and implementation of computational methods for several classes of difficult nonlinear problems, but, also including the derivation of analytic results in cases where these questions had not been settled before.

This grant was a continuation and extension of grant AFOSR-84-0315. This earlier grant had resulted in 26 papers over a 5-year period. The present grant resulted in the publication of 18 papers in refereed journals or refereed high-quality proceedings volumes and of one book. Several of the 26 papers generated under the earlier grant were listed as “to appear” in the final report for that grant. They all have appeared but are not listed here again. Instead, for simplicity, we refer to the papers and books produced under the present grant by giving the corresponding number in the list of all our publications which is a part of the attached curriculum vitae.
2. Major Areas of Completed Research

A rough classification of the research completed under the current grant would identify two major areas given below with the resulting publications. To keep the report concise we mainly list the relevant papers and comment shortly on additional work not reflected in those.

2.1 Development of computational methods for and study of free boundary problems for partial differential equations

The following papers were published in the respective sub-areas:

(a) Variational Inequalities: [54, 57, 58]
(b) Capillary Surfaces: [56, 60, 65, 68]

2.2 Stability of thermocapillary flows, efficient numerical solution and continuation for nonlinear partial differential equations

The following papers were published in the respective sub-areas:

(a) Thermocapillary convection: [55, 59, 61–64, 66, 67, 69–71]
(b) Efficient solution of PDEs: [1] (see below)

The work on 2.1(a),(b) was a continuation of earlier work, partly leading to a certain completion, as was, for example, documented in the survey work [57].

The work in 2.2(a) was also a continuation of research just begun at the end of the previous grant. Here, however, in a series of 11 papers alone major results were obtained settling the question of both energy and linear stability bounds for thermocapillary convection in the float-zone model of crystal growth, in particular under microgravity conditions and for realistic materials. The last paper cited, [71], contains a variety of computational and graphical results not given before. While the float-zone model will not further be investigated, thermocapillary convection, due to its increasing importance, will be subject of our future research. AFOSR, however, turned down a proposal which had this as a major component.

For 2.2(b) we only list one upcoming publication which we did not coauthor, but to which we have continued to contribute in a substantial way as is reflected in the Introduction and the Acknowledgements.


In addition, I presented my research at many colloquia and conference talks. Most of this is listed in the CV.
3. CURRICULUM VITAE

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Personal Data:
Born January 1, 1945; Permanent U.S. resident; Married 1971, three children

Education:
University of Mainz 1971 M.S. (Mathematics/Physics)
University of Darmstadt 1973 Ph.D. (Mathematics)
University of Darmstadt 1976 Habilitation (Mathematics)

Research and Teaching Interests:
Numerical solution of partial differential equations; finite elements; large-scale scientific computation for linear and nonlinear problems; multi-grid and other fast solution methods; numerical solution of bifurcation problems.

Academic Experience:

University of Mainz 1971-1973
Scientific Staff, Computing Centre
University of Darmstadt 1974-1977
Assistant/Associate Professor
University of Dortmund 1977-1984
Associate Professor/Professor
University of Bochum 1979-1980
Visiting Professor
Stanford University 1981 (Mar-Sept)
Research Visitor
Arizona State University 1982-1983
Visiting Professor
Arizona State University 1983-
Professor
University of Erlangen 1988 (Smr.-Sem.)
Visiting Professor
University of Heidelberg 1988 (Oct.)
Research Visitor
University of Jyväskylä 1991 (Smr.)
Visiting Professor
University of Leipzig 1992 (Oct.)
Research Visitor
Professional Societies:

Reviewer for Mathematical Reviews; Referee for various journals, the National Science Foundation and the Department of Defense; Editor of the International Series in Numerical Mathematics, Birkhäuser-Verlag, Basel

Grant Support
Continuation and Multi-grid Methods for Bifurcation Problems, AFOSR 84-0315 (10/1/84–11/30/89, $250,000, PI).

Stability and Instability of Thermocapillary Convection in Models of the Float-Zone Process, NAG 3-1054 NASA, Microgravity Science & Applications Division (6/15/89–9/30/92, $480,000, co-PI)

Spatio-Temporal Complexity and Large Scale Structures in Problems of Continuum Mechanics, AFOSR (URI), (9/1/89–9/30/92, $300,000, co-PI).


Selected invitations to conferences
1986 Efficient numerical methods in continuum mechanics, Kiel, Germany.
  Conference on nonlinear pde's, Salt Lake City, Utah.
  First World Congress on Computational Mechanics, Austin, Texas.
  AMS Regional Meeting, Logan, Utah.
  Finite Elements in Continuum Mechanics, Oberwolfach, Germany.

1987 Third Copper Mountain Conference on Multigrid Methods, Copper Mountain, Colorado.
  ASU Miniconference on Optimization, Tempe, Arizona.
  AMS-SIAM Summer Seminar on Computational Aspects of VLSI Design, University of Minnesota.
  German-U.S. American Workshop on New Applications and Algorithms for Optimal Control and Parameter Identification, Trier, Germany.
  Multigrid Methods, Oberwolfach, Germany.

  Fundamental Problems in Mechanics, Leipzig, Germany.
  Bifurcation Theory and its Numerical Analysis, Xi'an, PR China.
  Mathematical Modeling and Simulation of Electric Circuits, Oberwolfach, Germany.
  Numerical Treatment of Problems in Solid Mechanics, Bad Honnef, Germany.
1989 Fourth Copper Mountain Conference on Multigrid Methods, Copper Mountain, Colorado.
SIAM Annual Meeting, San Diego.
Computational Methods in Solid Mechanics, Oberwolfach, Germany.
Free Boundary Problems, Numerical Treatment & Optimal Control, Oberwolfach, Germany.
Computation of Nonlinear Flow and Instabilities, Austin, Texas.
Workshop on Continuation and Bifurcations: Numerical Techniques and Applications, Leuven, Belgium.
Miniconference on Newton-like Methods for Large-Scale Nonlinear Methods, Logan, Utah.

1990 Fourth International Conference on Computational and Applied Mathematics, Leuven, Belgium.
Contributions to the Numerics of Partial Differential Equations, Darmstadt, Germany.
Multigrid Methods, Oberwolfach, Germany.
Conference on Numerical Methods for Free Boundary Problems, Jyväskylä, Finland.

1991 Banach Center, 37th Semester on Numerical Analysis and Mathematical Modeling, Warsaw, Poland.
Bifurcation and Symmetry: Cross Influences between Mathematics and Applications, Marburg, Germany.

Short Course on Scientific Computing, Darmstadt, Germany.
Mathematical Modeling and Simulation of Electric Circuits and Semiconductors, Oberwolfach, Germany.
Surface Tension and Movement by Mean Curvature, Trento, Italy.
International Symposium on Numerical Analysis, Prague, Czechoslovakia.
First International Colloquium on Numerical Analysis, Plovdiv, Bulgaria.
Theory and Numerical Methods for Initial-Boundary Value Problems, Oberwolfach, Germany.

1993 Computational Methods for Nonlinear Phenomena, Oberwolfach, Germany.
International Conference on Advances in Geometric Analysis and Continuum Mechanics, Stanford, California.

1994 Motion by Mean Curvature and Related Topics, Trento, Italy.

Conferences/Sessions organized

1980 Bifurcation Problems and Their Numerical Solution, Dortmund, Germany.
1983 Numerical Methods for Bifurcation Problems, Dortmund, Germany.
1985 SIAM Fall Meeting, Tempe, Arizona.
1986 Continuation Methods and Algorithms, minisymposium at SIAM National Meeting, Boston.
1987 Nonlinear Parametrized Equations, minisymposium at ICIAM 87 meeting, Paris, France.
1989 Nonlinear Parameter Dependent PDEs and their Effective Solution, Tempe, Arizona.
1991 Stability Problems in Solid Mechanics, GAMM Workshop, Physics Center, Bad Honnef, Germany.
Selected invitations to Seminars/Colloquia

1984 University of Heidelberg, Germany
    Federal Institute of Technology,
    Lausanne, Switzerland
    University of Paderborn, Germany

1985 University of Hannover, Germany
    University of California, San Diego
    University of Darmstadt, Germany

1986 University of Bonn, Germany
    Free University of Berlin, Germany
    Fraunhofer Institute for Microelectronics, Duisburg, Germany
    Southern Methodist University, Dallas

1987 University of Wyoming, Laramie
    University of Lyon, France
    University of Grenoble, France
    Universität der Bundeswehr, Munich, Germany
    University of Erlangen, Germany
    University of Darmstadt, Germany
    University of Nijmegen, Netherlands
    University of Freiburg, Germany

1988 University of Mainz, Germany
    University of Konstanz, Germany
    Technical University of Berlin, Germany
    University of Paderborn, Germany
    University of Münster, Germany
    University of Cologne, Germany
    University of Darmstadt, Germany
    University of Augsburg, Germany
    University of Würzburg, Germany
    University of Heidelberg, Germany
    University of Hamburg, Germany
    University of Karlsruhe, Germany
    University of Kaiserslautern, Germany

1989 University of Ulm, Germany
    University of Heidelberg, Germany

1990 University of Darmstadt, Germany
    University of Heidelberg, Germany
    North Carolina State University
    University of Aachen (RWTH), Germany

1991 University of Kiel, Germany
    University of Heidelberg, Germany
    University of British Columbia, Canada

1992 University of Stuttgart, Germany
    University of Tübingen, Germany
    Stanford University
    Los Alamos National Laboratory
    University of Leipzig, Germany
    Technical University of Dresden, Germany

1993 University of Darmstadt, Germany
    University of Clausthal, Germany
    University of Leipzig, Germany
    University of Frankfurt, Germany

1994 Emory University
    Georgia Institute of Technology
PUBLICATIONS OF HANS D. MITTELMANN


47. A free boundary problem and stability for the rectangular plate (with E. Miersemann), Math.


49. The augmented Skeleton method for parametrized capillary surfaces, in Proceedings of the

50. On the stability in obstacle problems with applications to the beam and plate (with E.

51. Energy stability of thermocapillary convection in a model of the float-zone, crystal-growth
process (with Y. Shen, G.P. Neitzel and D. F. Jankowski), J. Fluid Mech. 217, 639-660

52. Computing stability bounds for thermocapillary convection in a crystal-growth free boundary
problem, in “Free Boundary Problems,” K.-H. Hoffmann, J. Sprekels (eds.), ISNM 95, 165-

53. Stability of Marangoni convection in a microgravity environment, in “Continuation and
Bifurcations: Numerical Techniques and Applications,” D. Roose, B. De Dier, and A.

54. The nonlinear beam via optimal control with bounded state variables (with H. Maurer),

55. A large sparse and indefinite generalized eigenvalue problem from fluid mechanics (with C.

56. Computation of parametrized capillary surfaces, in “Contributions to the Numerics of Partial
Differential Equations,” THD Schriftenreihe Wissenschaft und Technik, vol. 52, 187-202,

57. Stability and continuation of solutions to obstacle problems (with E. Miersemann), J. Comp.

58. Stability in obstacle problems for the von Karman plate (with E. Miersemann), SIAM J.

59. Stability of thermocapillary convection in float-zone crystal growth (with C. Law, D.F.
Jankowski, G.P. Neitzel), in “Numerical Methods for Free Boundary Problems,” P.

60. Bifurcation of axially symmetric capillary surfaces (with U. Hornung), J. Colloid Interface Sci.

61. Stability and instability of thermocapillary convection in models of float-zone crystal growth

62. Energy stability of thermocapillary convection in a model of the float-zone crystal-growth


BOOKS/EDITORIALS

