Memoirs of the Scientific Sections of the Romanian Academy
Tome XXXVI, 2013

BOOK REVIEWS

M.C. DELFOUR, *Introduction to Optimization and Semidifferential Calculus*, SIAM, Philadelphia, 2012, xv + 353 p., ISBN: 978-1-611972-14-6.

Optimization with its calculus of variations (shortly, the study about the minima and/or maxima of a function), founded as early as 1638 by Fermat, is one of the most important and interesting fields in Mathematics, with various applications in economics, statistics, computer sciences, engineering or decision-making theory.

The book is an initiation to nondifferentiable optimization with respect to variables belonging to finite-dimensional spaces, emphasizing the semidifferential calculus.

The first chapter presents the content of the book and some background of classical analysis.

Chapter 2 offers some results about the existence of minimizers of real-valued functions including elements of convex analysis, such as Ekeland's variational principle and the notion of Frenchel-Legendre transform.

Chapter 3 contains some basic results on continuity and differentiability of the functions of one and several real variables. Then a semidifferential calculus is developed, extending the classical differential one, by introducing notions of semidifferentials (particularly Hadamard semidifferentials).

Chapter 4 provides some optimality conditions to characterize an unconstrained or a constrained extremum, considering first twice differentiable functions without constraints and then the necessary and sufficient conditions for convex differentiable objective functions and convex sets of admissible points. Also, a general necessary optimality condition for a local minimum using the upper Hadamard semidifferentiability of the objective function and Bouligand's tangent cone of admissible directions is given.

Chapter 5 provides some differentiable optimization problems regarding equality and inequality constraints.

The book is written in a proper mathematical style, containing definitions, theorems and detailed proofs. Numerous examples and exercises are included in each chapter, their solutions being given in Appendix B.

This work is intended to be a text book for a course at undergraduate level for students in Mathematics, Physics, Engineering, Economics and other disciplines, with basic knowledge on mathematical analysis and linear algebra.

Anca Croitoru

ALFIO BORZI, VOLKER SCHULZ, *Computational Optimization of Systems Governed by Partial Differential Equations*, Computational Science and Engineering, SIAM, 2012, xx+282 p., ISBN: 978-1-611972-04-7.

In this book, the authors present some recent results and outline developments in the field of the numerical solution of PDE optimization problems.

The computational techniques discussed in the volume represent recent developments resulting mainly from the combination of modular techniques for the numerical solution of PDE's and of sophisticated optimization schemas. Focus of the book is on methodological aspects. Problems with elliptic, parabolic and hyperbolic PDE's and coupled systems of PDE's are considered. A chapter of applications is presented with the purpose of outlining important emerging application topics, such as shape optimization, quantum control and time-dependent electromagnetic inverse problems.

The book may serve as a textbook for graduate students, for researchers in the field of scientific computing with PDEs and also for specialists in natural sciences and engineering.

Cristina Stamate

YAIR SHAPIRA, *Solving PDEs in C++. Numerical Methods in a Unified Object-Oriented Approach*, Second Edition, SIAM, Philadelphia, 2012, xxxii + 776 p., ISBN 978-1-611972-16-0.

The book offers a completely open object-oriented framework to solve problems in numerical modeling and engineering. The book introduces advanced numerical methods, such as adaptive finite elements ant multigrid. It uses the powerful programming tools available in C++ to implement these methods.

The book leads the reader along the entire solution process, from the original PDE, through the discretization stage, to the numerical solution of the resulting discrete system. The applications in the book stretch from image processing and cryptography to systems of nonlinear PDEs in 3D adaptive meshes.

The book contains seven parts. The first and second parts introduce briefly the programming language and the object-oriented approach. The third and fourth parts discuss and implement finite differences and elements. The fifth part deals with numerical linear algebra and parallelism. The sixth and seventh parts use the C++ code to solve systems of nonlinear PDEs in two and three spatial dimensions, including elasticity, Stokes, Navier-Stockes, Maxwell, and Helmholtz equations. Each chapter ends with relevant exercises and solutions.

Ana-Maria Moşneagu

UWE NAUMANN, *The Art of Differentiating Computer Programs: An Introduction to Algorithmic Differentiation*, SIAM, Philadelphia, 2012, XVIII + 340 p., ISBN: 978-1-611972-06-1.

With this volume, the author wants to first write an entry-level book on algorithmic (also known as automatic) differentiation (AD), providing fundamental rules for the generation of first- and higher -order tangent-linear and adjoin code. The author shows that to reveal their full power, AD solutions must be integrated into the existing numerical simulation software. There are presented two ways of implementing AD. This book describes a set of techniques for modifying the semantics of numerical simulation programs, so that the first and higher derivatives should be computed accurately and efficiently.

The book is structured into five chapters and an Appendix.

Chapter 1 motivates the use of differentiated computer programs in the context of methods for the solution of systems of nonlinear equations and for nonlinear programming. Also, the drawbacks of closed-form symbolic differentiation and finite difference approximations are discussed, and the superiority of adjoin over tangent-linear cod,e if the number of inputs exceeds the number of outputs significantly, is shown.

The subject of Chapter 2 is the generation of tangent linear and adjoin code by forward and reverse AD mode. Two methods are considered for implementing the tangent-linear and adjoin models: source transformation and operator overloading.

Chapter 3 presents more dataon the generation of second or higher-order tangent-linear and adjoin code. Second – and higher-order tangent-linear code is obtained by recursive application of forward AD mode. The author shows that the second-and higher-order tangent-linear and adjoin code can be used to accumulate the corresponding derivative tensors or projections thereof.

Chapter 4 is dedicated to all those who are interested in technical issues related to derivative code compilers. The author relates the well-known materials from compiler construction to the task of differentiating computer programs. The scanner and parser generators flex and bison are used to build a compiler front-end suitable to both single - and multipass compilation of derivative code.

Chapter 5 presents the results in the form of a fully functional prototype derivative code compiler for a small subset of C++. This last chapter combines the material presented in the previous chapters to form the prototype derivative code compiler dcc. The use of dcc for the generation of first derivative code and of dcc for the partial automation of the corresponding source transformation is presented.

Further relevant material, including hints on the solutions for all exercises, is collected in the Appendix.

In each chapter, readers will find many examples and exercises, including hints to solutions. Project-style exercises come with detailed hints on possible solutions. All software is provided as an open source. In addition, readers will have access to an additional website containing sources of all softwares discussed in the book, additional exercises and comments on their solutions (growing over the coming years), links to other sites on AD, and errata.

This book is dedicated to undergraduate and graduate students in computational science, engineering and finance, as well as to applied mathematics and computer science specialists, but it is also recommended for researchers and developers who need an introduction to AD.

Marius Apetrii

ALAN J. LAUB, *Computational Matrix Analysis*, SIAM, Philadelphia, 2012, xiii+154 p., ISBN: 978-1-611972-20-7.

The book, addressing students, scientists and engineers, is an introduction to computational matrix analysis or numerical linear algebra. This book is intended for students and researchers interested in quickly learning the fundamentals of numerical linear algebra.

The book is structured into eleven chapters: Preliminaries and Notation, Introduction to Finite Arithmetic, Conditioning and Numerical Stability, Introduction to Rounding Analysis, Numerical Matrix Algebra, Gaussian Elimination, Solving Linear System, Linear Least Squares Problems, Computing Eigenvalues and Eigenvectors, Other QR-Type Algorithms, Applications.

The book opens with a brief review of notation and some of the topics in conventional matrix analysis. Further, an introduction to finite arithmetic is given, followed by examples describing problems in stability and rounding analysis¸ as well as an introduction to some mathematical software topics related to numerical linear algebra. An introduction to Gaussian elimination is discussed and a chapter on linear least squares covers orthogonal reduction and QR factorization is given. The eigenvalue and eigenvectors problems are also discussed. The last chapter of the book includes applications of the algorithms described in the previous chapters.

To conclude with, this is a valuable book of Applied Mathematics which provides theoretical results and many examples useful to understand and to apply these results and the proposal algorithms.

Ionel-Dumitrel Ghiba

ADRIAN CONSTANTIN, *Nonlinear Water Waves with Applications to Wave-Current Interactions and Tsunamis,* SIAM, Philadelphia, 2011, xii + 317 p., ISBN: 978-1-611971-86-6.

The book is devoted to recent developments in nonlinear water waves. The author discusses the underlying physical factors of such waves and explores the physical relevance of the mathematical results here presented. Many important results are proved in full, while for others the proofs are only sketched.

The main themes of the present book are: investigation of waves-current interactions (existence theory of steady two-dimensional water waves propagating at the surface of water with a flat bed in a flow with a general vorticity distribution); elucidation of the flow pattern beneath the irrotational steady water waves propagating at the surface of water with a flat bed, discussing both the Stokes waves as well as the solitary waves; wave breaking provided by some integrable model equations arising in the shallow-water regime; tsunami modeling.

The analytical results are discussed and described in accordance with numerical simulations and experimental results.

The second chapter presents the physical concepts and the basic equations for water waves. A short mathematical background is also given. The third chapter is devoted to an in-depth study of two-dimensional symmetric periodic travelling waves propagating at the free surface of water with a flat bed in a flow without stagnation points. The fourth chapter considers the problem of particle trajectories and of pressure beneath a Stokes wave. The aim of the fifth chapter is to discuss some aspects of solitary water waves, while the sixth chapter studies the breaking waves. The importance of the mathematical results can be clearly viewed in the last chapter devoted to the modeling of tsunami. Each chapter proposes new directions in which studies can be further developed.

The book was written to help researchers in many branches (mathematics, engineering, physics). Introductory material and discussions are accessible for newcomers in the field and motivate the reader to further follow the results presented in the book.

Ionel-Dumitrel Ghiba

MARTIN EHRENDORFER, *Spectral Numerical Weather Prediction Models*, SIAM, Philadelphia, 2012, xxv + 498 p., ISBN: 978-1-611971-98-9.

The topic of the book is numerical weather prediction (NWP). The approach focuses on the application of the spectral method in NWP models. This book is unique as it illustrates spectral theory in terms of its practical application and it discusses all aspects of a global NWP model built on the spectral method. The mathematical developments are illustrated by numerous examples and data tables and figures.

The work is structures into three parts and twelve chapters. The last part contains appendices (technical details on vector analysis, curvilinear coordinate system, associated Legendre functions, and spherical harmonics). Part I includes: a basic introduction, including general comments on the spectral method and on the principles governing atmospheric dynamics, a development of a hierarchy continuous formulated atmospheric models, a few selected fundamental atmospheric-dynamic topics. Part II includes: an essential introduction to the spectral methods, practical aspects of the Galerkin and collocation strategies, illustrating the transform method and the problem of aliasing by examples, the model design of PEAK (Primitive-Equation Atmospheric Research Model Kernel), with details on the specific use of the transform method and on the vertical and temporal discretization of PEAK, numerical implementation, validation, and the simplified configurations of PEAK. The PEAK source code is resumed in the last appendix.

Summarily, the book combines mathematical and engineering results to give complete descriptions of the considered problems. It addresses graduate students and researchers interested in any aspect of Numerical Weather Prediction and in fundamentals of atmospheric dynamics, from mathematical and engineering point of views.

Ionel-Dumitrel Ghiba

NIKOLAI P. OSMOLOVSKII, HELMUT MAURER, *Applications to Regular and Bang-Bang Control. Second-OrderNecessary and Sufficient Optimality Conditions in Calculus of Variations and Optimal Control*, Advances in Design and Control, SIAM, Philadelphia, 2012, xviii + 382 p., ISBN 978-1-611972-35-1.

This book provides a comprehensive exposition on the theory and applications of second-order necessary and sufficient optimality conditions in the calculus of variations and optimal control. More specifically, the authors consider control problems where the dynamics is given by ordinary differential equations subject to boundary conditions of equality and inequality type, with constraints of mixed state-control type. Particular attention is given to the case of broken extremals, where the control has finitely many points of discontinuity. A characteristic of the text is that necessary and sufficient conditions are given in the form of no-gap conditions. Various applications are given in many different directions, often accompanied by numerical examples.

The text is divided into two parts, the first one mostly devoted to the theory of quadratic conditions for smooth problems of the calculus of variations, while the second one is treating optimal control problems, with emphasis on bang-bang controls. Each part consists in four chapters; they are described below.

In the first chapter, the authors present the abstract theory of higher-order conditions used in order to derive quadratic optimality conditions in the smooth case. The second chapter focuses on the quadratic theory of conditions for a Pontryagin minimum in the general problem of the calculus of variations without local mixed constraints. The method here used is the decoding of the basic constant for the set of so-called “Pontryagin sequences” and a special higher order, introduced previously. By estimating the basic constant, both necessary and sufficient conditions are obtained. Extension of these results to the case of local mixed constraint is presented in Chapter 3, by means of a special method of projection. The fourth chapter is devoted to the derivation of tests for positive semi-definiteness and for positive definiteness of a certain quadratic form on the critical cone; these serve as necessary, respectively sufficient conditions for local minimum when dealing with broken extremals.

In the first chapter of the second part the authors derive quadratic optimality conditions for optimal control problems when the vector control variable has two components: a continuous unconstrained control appearing nonlinearly and a control appearing linearly and belonging to a convex polyhedron. The second component is assumed to be of bang-bang type. The pure bang-bang case is investigated in Chapters 6 and 7, where the second-order optimality conditions are derived in two different, but equivalent forms. The last chapter of the book is devoted to numerical methods for solving the solutions of a finite-dimensional optimization problem induced by the bang-bang control and then testing the second-order conditions.

This book is valuable to researchers in the calculus of variations and optimal control. It is also suitable to researchers and engineers who use applications of optimal control in wide areas of interest, ranging from physics or biological engineering to economics.

Adrian Zălinescu

WEI-MING NI, *The Mathematics of Diffusion*, SIAM, Philadelphia, 2011, xii + 110 p., ISBN: 978-1-611971-96-5.

Diffusion has been extensively used in many disciplines of science to model a wide variety of phenomena. Therefore, there are lots of works which treat this subject. One of this works is the book entitled “The mathematics of diffusion”, treating a number of models, like Gierer-Meinhardt system, Lengyel-Epstein model, Lotka-Voltera competition-diffusion system, and others, in order to illustrate the behind mathematics, and also to make the reading more interesting. It can be noticed the pronounced didactic character of this work, and this is because the book is an expanded version of the lectures delivered by the author at Tulane University. Chapers 1 and 2 present fundamental notions about difussion equations with both Dirichlet and Neumann boundary conditions, and also questions on stabilization of solutions, including the rate of convergence. Therefore, it represents a good tool for the young researchers and students interested in elliptic or parabolic equations and in mathematical biology, which are at the beginning of their research in this field.

Chapter 3 is dedicated to the analysis of steady state solutions. The important role plaied by the steady state in the dynamics of solutions to parabolic equations is known. It should be mentioned that the results are presented rather from the dynamic systems point of view, than from the functional analysis point of view. The author studies the relation between the „shape" of the steady states and its stability property.

The next chapter explores the interactions between diffusion and spatial heterogeneity, by following the theory developed by Cantrell, Cosner and Lou and others in mathematical ecology. As main example it is considered the Lotka-Volttera competition-diffusion system, where the interaction between diffusion and spatial heterogeneity creates different interesting phenomenas.

It should be also mentioned that this book contains lots of important open problems for readers to investigate.

Ionuţ Munteanu

YUTAKA YAMAMOTO, *From Vector Spaces to Function Spaces. Introduction to Functional Analysis with Applications*, SIAM, 2012, xiv + 268 p., ISBN 978-1-611972-30-6.

This book has a dual purpose: one is to provide young students an accessible account of a conceptual understanding of fundamental tools in applied mathematics. The other is to give those who already have some exposure to applied mathematics, but wish to acquire a more unified and streamlined comprehesion of this subject, a deeper understanding through background motivations.

The book starts (Chapters 1-4) with some basics in vector spaces and infinite-dimensional spaces (Banach spaces, Hilbert spaces). The following chapters (Chapters 6–9) presents Schwartz distributions, Fourier analysis, Laplace transforms, Poisson integrals and Hardy spaces. Chapter 10 is devoted to basic linear control systems theory. For a more complete understanding, an Appendix concerning some background on sets, mappings and topology and an Appendix containing bibliographical notes are given.

The book intends to give an accessible account of applied mathematics mainly of analysis subjects, with emphasis on functional analysis.

Cristina Stamate

LORENZ T. BIEGLER, STEPHEN L. CAMPBELL,VOLKER MEHRMANN (Editors), *Control and Optimization with Differential-Algebraic Constraints*, SIAM, Philadelphia, 2012, xii + 344 p., ISBN: 978-1-611972-24-5.

The aim of this book is to the present cutting-edge theory and numerical methods for the optimal control of differential-algebraic equations (DAEs), which form one of the most flexible and simple ways to model a physical system. In this respect, the volume is equally intended as a guide to modelling complex systems in science and engineering with DAEs. Once provided a DAE model for a real-world system, it becomes a tool for controlling and optimizing the performance of the system it models.

The book is written in a very readable manner by leading experts from academia and industry, with backgrounds in mathematics, scientific computing, chemical engineering, aerospace engineering, mechanical engineering, and computer science. Each of the sixteen chapters is presented in the form of an article whose author (or authors) participated to the workshop *Control and Optimization with Differential-Algebraic Constraints*, held in Banff, Canada, between Oct. 24-29, 2010.

The first chapter is written by the organizers of the event and is an introduction to the topic of DAEs, providing a brief overview of DAE representations and properties, as well as their control and optimization. The subsequent chapters explore in more detail these issues; among the covered topics there are included: reformulation and regularization of DAE control problems, Pontryagin's minimum principle, optimization with differential-algebraic constraints, stabilization, behavior of perturbations, linear-quadratic optimal control, direct transcription approach, optimal control problems with state delays, unknown parameter estimation. Throughout the volume, many examples of applications are given, mostly to illustrate the newly developed results and algorithms. While, the final four chapters are entirely devoted to specific real-world applications: synthesis of a chemical process control strategy, control and optimization of building temperature regulation, biomedical imaging application considered as an inverse problem, optimization of batch and semibatch processes currently applied in chemical and pharmaceutical industry.

This book is suitable to those working on real-world applications, especially in control of problems appearing in chemical and mechanical engineering, but as well as to those developing methods and theory in the area of optimal control of DAEs.

Adrian Zălinescu

DANIELA CALVETTI, ERKKI SOMERSALO, *Computational Mathematical Modeling*. *An Integrated Approach Across Scales*, SIAM, Philadelphia, 2013, xii + 222 p., ISBN 978-1-611972-47-4.

This book, intended for advanced undergraduate students and researchers interested in mathematics, engineering, and physical and life science, draws a path in the mathematical modelling, the considered models being close to the practice.

The book is structured into nine chapters. The first chapter reviews background material while the second one is dedicated to simple compartment models. A description of a model in terms of a continuous model is described in Chapter 3. Scaling of models is analysed in Chapter 4. The first four chapters are concerned with deterministic models, while the last chapters consider stochastic models. An introduction in stochastic models is given in Chapter 5, while the important concept of noise is discussed in Chapter 6. The waiting processes and Markov processes are introduced in Chapters 7 and 8. Chapter 9 discusses the concept of agent-based stochastic modelling and stochastic cellular automata.

Each chapter ends with a small section suggesting references. Moreover, each chapter contains a number of exercises.

To conclude with, this is a valuable book of Applied Mathematics which provides theoretical results and many useful examples to understand and to apply both these results and the proposed algorithms.

Ionel-Dumitrel Ghiba

TATSIEN LI, TIEHU QIN (translated by YACHUN LI), *Physics and Partial Differential Equations,* vol. I, SIAM, Philadelphia, 2012, x + 264 p., ISBN 978-1-611972-26-9.

This book helps the readers who are more familiar with mathematics than physics to discover the connection between various physical and mechanical disciplines and their related mathematical models, which are described by partial differential equations (PDEs). The authors establish the fundamental equations for fields such as: electrodynamics; fluid dynamics, magnetohydrodynamics, and reacting fluid dynamics; elastic, thermoelastic, and viscoelastic mechanics; the kinetic theory of gases; special relativity; and quantum mechanics.

The first volume of this book is structured into five chapters. The contents of each chapter is relatively independent jet the structure is coherent.

This book, realizing a deep investigation of important models from continuous mechanics, is well written, which makes it easily accessible to undergraduate students and researchers interested in mathematics, engineering, and physical and life science.

Ionel-Dumitrel Ghiba

GRIGORIY BLEKHERMAN, PABLO A. PARRILO, REKHA R. THOMAS (Editors), *Semidefinite Optimization and Convex Algebraic Geometry*, MOS-SIAM Series on Optimization, SIAM/MOS, Philadelphia, 2013, xix + 476 p., ISBN: 978-1-611972-28-3.

The book presents the foundations of convex algebraic geometry and provides an accesible entry point for students and researchers. The book begins with an introduction to nonnegative polynomials and sums of squares and their connections to semidefinite programming, and quickly advances to several areas at the farefront of current research, such as semidefinite representability of convex sets, duality theory from the point of view of algebraic geometry and nontraditional topics, such as sum of squares of complex forms and noncommutative sums of squares polynomials.

The book can serve as a textbook for graduate-level courses, presenting the basic mathematics behind convex algebraic geometry and semidefinite optimization.

Cristina Stamate

LLOYD N. TREFETHEN, *Approximation Theory and Approximation Practice*, SIAM, Philadelphia, 2013, viii + 305 p., ISBN: 978-1-611972-39-9.

The book under review represents an exhaustive survey of ideas and results concerning the constructive approximation of functions. The presented topics are illustrated computationally with the Chebfun software package in Matlab. The main body of the book is divided into 28 chapters and an appendix. The author considers the following subjects: Chebyshev polynomials and series; barycentric interpolation formula; Weierstrass approximation theorem; Gibbs phenomenon; Hermite integral formula; potential theory and approximation; Runge phenomenon; best and near-best approximations; Carathéodory Fejér approximation; spectral methods; nonlinear approximation; Padé approximation etc.

Due to its clear and well illustrated approach, the book will be useful for advanced undergraduate or graduate students who have taken courses in numerical and complex analysis and Matlab.

Victor Postolache