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Geno Nikolov · Natalia Kolkovska
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Editors
Geno Nikolov
Sofia University "St. Kliment Ohridski"
Sofia, Bulgaria

Krassimir Georgiev
Bulgarian Academy of Sciences
Sofia, Bulgaria

Natalia Kolkovska
Bulgarian Academy of Sciences
Sofia, Bulgaria

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Preface

The ninth issue of the series of international conferences on Numerical Methods and Applications (NMA 2018) held in Bulgaria took place in the beautiful resort Borovets during the period August 20–24, 2018. The conference was organized by the Faculty of Mathematics and Informatics of Sofia University St. Kliment Ohridski, in co-operation with two institutes of the Bulgarian Academy of Sciences: the Institute of Mathematics and Informatics and the Institute of Information and Communication Technologies.

In total, 112 participants from 23 countries all over the world attended the conference. The nice weather and the fresh air of Rila mountain highly contributed to the creative atmosphere of the conference, providing an opportunity for researchers to present their recent achievements, share ideas, continue existing or start new fruitful scientific cooperations.

A wide range of problems concerning both recent theoretical advances in numerical methods and the application of numerical methods in mathematical modeling were discussed at NMA 2018. In total, 92 talks, including four plenary lectures, were delivered at the conference. Five special sessions featured in the scientific program: Numerical Search and Optimization, Problem-driven Numerical Methods, Numerical Methods for Fractional Diffusion Problems, Orthogonal Polynomials and Numerical Quadratures, and Monte Carlo and Quasi-Monte Carlo Methods, along with a stream of talks that formally do not fall into these sessions.

This volume contains 56 papers, based on the talks of the participants at NMA 2018, including the plenary lectures of Jean-Claude Latché (France) and Francisco Gaspar (The Netherlands). The abstracts of the other two plenary lectures, delivered by Jun Hu (China) and Rafael Kruse (Germany), are also presented here. Each of the papers in this volume has passed a single-blind review procedure. We thank all the authors who contributed to the volume.

The success of NMA 2018 would not have been possible without the joint efforts and hard work of many colleagues from various institutions and organizations. We are grateful to all members of the Organizing and Scientific Committees, to the organizers of the special sessions, and to all reviewers. We are also thankful to the local staff for the excellent service.

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November 2018

Geno Nikolov
Natalia Kolkovska
Krassimir Georgiev

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Abstract of Invited Talks

Adaptive and Multilevel Mixed Finite Element Methods

Jun Hu

Peking University, Beijing, China
hujun@math.pku.edu.cn

The problems that are most frequently solved in scientific and engineering computing may probably be the elasticity equations. The finite element method (FEM) was invented in analyzing the stress of the elastic structures in the 1950s. The mixed FEM within the Hellinger–Reissner (H-R) principle for elasticity yields a direct stress approximation since it takes both the stress and displacement as an independent variable. The mixed FEM can be free of locking for nearly incompressible materials, and be applied to plastic materials, and approximate both the equilibrium and traction boundary conditions more accurate. However, the symmetry of the stress plus the stability conditions make the design of the mixed FEM for elasticity surprisingly hard. In fact, "Four decades of searching for mixed finite elements for elasticity beginning in the 1960s did not yield any stable elements with polynomial shape functions" [D. N. Arnold, Proceedings of the ICM, Vol. I: Plenary Lectures and Ceremonies (2002)]. Since the 1960s, many mathematicians have worked on this problem but compromised to weakly symmetric elements, or composite elements. In 2002, using the elasticity complexes, Arnold and Winther designed the first family of symmetric mixed elements with polynomial shape functions on triangular grids in 2D.

The first part of the talk presents a new framework to design and analyze the mixed FEM of elasticity problems, which yields optimal symmetric mixed FEMs. In addition, those elements are very easy to implement since their basis functions, based on those of the scalar Lagrange elements, can been explicitly written down by hand. The main ingredients of this framework are a structure of the discrete stress space on both simplicial and product grids, two basic algebraic results, and a two-step stability analysis method.

The second part of the talk gives a unified analysis of both convergence and optimality of adaptive mixed finite element methods for a class of problems when the finite element spaces and corresponding a posteriori error estimates satisfy five hypotheses. We prove that these five conditions are sufficient for convergence and optimality of the adaptive algorithms under consideration. The main ingredient for the analysis is a new method to analyze both discrete reliability and quasi-orthogonality. As applications, we prove these five hypotheses for the Raviart–Thomas and Brezzi–Douglas–Marini elements of the Poisson and Stokes problems in both two and three dimensions. To extend the above result to linear elasticity problems, we propose a reliable and efficient a posteriori error estimator for the symmetric mixed finite element methods for linear elasticity problems. In addition, we construct nested mixed finite elements by relaxing C^0 continuity of the existing mixed elements in the literature.

The third part of the talk constructs a block diagonal preconditioner with the minimal residual method and a block triangular preconditioner with the generalized minimal residual method for the symmetric mixed finite element methods of linear elasticity. A fast auxiliary space preconditioner based on the H^1 conforming linear element of the linear elasticity problem is then designed for solving the Schur complement. For both diagonal and triangular preconditioners, it is proved that the conditioning numbers of the preconditioned systems are bounded above by a constant independent of both the crucial Lamé constant and the mesh-size.

Error Analysis of Randomized Time-Stepping Methods for Non-autonomous Evolution Equations with Time-Irregular Coefficients

Raphael Kruse

Technische Universität Berlin, Straße des 17. Juni 136, 10623 Berlin, Germany
kruse@math.tu-berlin.de

In this talk, we consider the numerical approximation of Carathéodory-type differential equations of the form

$$u'(t) = f(t, u(t)), \quad t \in (0, T), \quad u(0) = u_0,$$

and of nonlinear and non-autonomous evolution equations of the form

$$u'(t) + \mathcal{A}(t)u(t) = f(t), \quad t \in (0, T), \quad u(0) = u_0,$$

where f and $\mathcal{A}$ may be discontinuous with respect to the time variable. In this non-smooth situation, it is notoriously difficult to construct numerical algorithms with a positive convergence rate. In fact, it can be shown that any deterministic algorithm depending only on point evaluations may fail to converge if, for instance, $\mathcal{A}$ and f only satisfy an L^2-integrability condition with respect to t.

Instead, we propose to apply randomized Runge–Kutta methods to such time-irregular evolution equations as, for instance, a randomized version of the backward Euler method. We obtain positive convergence rates with respect to the mean-square norm under considerably relaxed temporal regularity conditions. An important ingredient in the error analysis consists of a well-known variance reduction technique for Monte Carlo methods, the stratified sampling. We demonstrate the practicability of the new algorithm in the case of a fully discrete approximation of a more explicit parabolic PDE.

This talk is based on joint works [1, 2] with Monika Eisenmann (Technische Universität Berlin), Mihály Kovács and Stig Larsson (both Chalmers University of Technology) as well as Yue Wu (University of Edinburgh).

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