

# Preface

The design and implementation of numerical models that accurately capture the appropriate model features of complex physical systems described by time-dependent coupled systems of nonlinear PDEs present one of the main challenges in today's scientific computing. This volume integrates works by experts in computational mathematics, and its applications focused on the modern algorithms which are in the core of accurate modeling: adaptive finite-element methods, conservative finite-difference and finite-volume methods, and multilevel solution techniques. Fundamental theoretical results are revisited in several survey articles, and new techniques in numerical analysis are introduced. Applications showing the efficiency, reliability, and robustness of the algorithms in porous media, structural mechanics, and electromagnetism are presented.

The volume consists of papers prepared in the context of the International Symposium "Numerical Solution of Partial Differential Equations: Theory, Algorithms and their Applications" in honor of Professor Raytcho Lazarov's 40 years of research in computational methods and applied mathematics and on the occasion of his 70th birthday.

The symposium was organized and sponsored by the Institute of Information and Communication Technologies (IICT), Bulgarian Academy of Sciences (BAS), Lawrence Livermore National Laboratory (USA), and Department of Mathematics, The Pennsylvania State University (USA). Members of the program committee are Oleg Iliev (ITWM Fraunhofer, Kaiserslautern, Germany), Peter Minev (University of Alberta, Canada), Svetozar Margenov (Institute of Information and Communication Technologies, BAS), Panayot Vassilevski (Lawrence Livermore National Laboratory, USA), and Ludmil Zikatanov (The Pennsylvania State University, USA).

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The editors are grateful to the Institute of Information and Communication Technologies (IICT), Bulgarian Academy of Sciences, the Lawrence Livermore National Laboratory, and the Department of Mathematics at Penn State for the support of the symposium.

On behalf of all the contributors, we dedicate this volume to our teacher, friend, and colleague Raytcho Lazarov.

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## On the Occasion of the 70th Anniversary of Raytcho Lazarov

With great pleasure we introduce this collection of papers in honor of Raytcho Lazarov, professor at the Texas A&M University and Doctor of Sciences and Doctor Honoris Causa of the “St. Kliment Ohridski” University of Sofia, Bulgaria.

Raytcho Lazarov is a computational mathematician of extraordinary depth and breadth whose work has had and continues to have exceptional impact on computational and applied mathematics. He has authored or coauthored more than 200 journal publications and 4 books spanning all major areas in computational mathematics and bridging mathematical theory and scientific computing with sciences and engineering.

Raytcho Lazarov was born in Kardzhali (Кърджали), Bulgaria, on January 23, 1943. He graduated from “St. Antim I” High School in Zlatograd (Златоград) and in 1961 went to Sofia University “St. Kliment Ohridski” to continue his studies in the Department of Mathematics (industrial profile). During his first year as a college student, Raytcho demonstrated his talent for mathematics, and his dedication to study it, and he was selected to continue his education at the University of Wroclaw in Poland in 1963. In Wroclaw Raytcho was able to interact with many distinguished mathematicians from the Polish mathematical school and received first-rate mathematical training.

In 1968 Raytcho Lazarov was admitted to the PhD program of the Moscow State University. As a graduate student in Moscow, he studied and worked under the supervision of Academician A. A. Samarskii who was one of the best contemporary computational mathematicians in the world. Lazarov’s thesis work was on “Finite difference schemes for elasticity problems in curvilinear domains,” among the first rigorous studies of numerical approximations of problems in structural mechanics.

After receiving his PhD degree in 1972, Raytcho Lazarov worked as a research associate and senior research associate in the Institute of Mathematics (IM) of the Bulgarian Academy of Sciences (BAS) until 1987. During this time he established himself as one of the leading experts in numerical analysis. In 1976 Raytcho Lazarov visited the Rutherford Laboratory in Didcot, UK, for one year, and this visit had notable impact on his future research. His focus shifted to the theory and applications of the finite element method (FEM) which remains to be his primary field of research to this day.

Lazarov earned the degree of doctor of sciences in June 1982 with a thesis on “Error estimates of the difference schemes for some problems of mathematical physics having generalized solutions.” This thesis contained several breakthrough results, which were published in more than 10 papers and formed the basis for a research monograph that he coauthored with A. A. Samarskii and V. Makarov, *Difference Schemes for Differential Equations Having Generalized Solutions*, which was published in 1987.

In 1986 Lazarov’s superb scientific achievements earned him the title of a professor of mathematics at the Institute of Mathematics of the Bulgarian Academy of Sciences, a position that he continues to hold to this day. His leadership ability

was also recognized by his colleagues, and in 1985 he became the head of the Laboratory on Numerical Analysis, BAS, and a deputy-director of the Laboratory on Parallel Algorithms and High Performance Computer Systems, BAS. In 1986 Lazarov became deputy-director of the newly established Center for Informatics and Computer Technology (CICT) at BAS. This was one of the first interdisciplinary centers worldwide for mathematical research on advanced algorithms for the emerging parallel computer systems. He played a crucial role in hiring a cohort of the best young applied mathematicians in Bulgaria—Djidjev, Vassilevski, Margenov, Dimov, Bochev, and many more. In fact, Raytcho Lazarov's leadership was the key in making CICT one of the best places for large-scale scientific computing and parallel algorithms. In 1984 Raytcho initiated a series of international conferences on numerical methods and applications in Sofia, Bulgaria, which helped to publicize the results and achievements of the Bulgarian numerical analysts and to integrate them into the international community.

Such accomplishments were noticed by his colleagues around the world. Vidar Thomée helped Raytcho to get a visiting position at the University of Wyoming in 1987. This turned out to be a critical point in Lazarov's career. In Wyoming he met and befriended Richard Ewing who at that time was a director of the Enhanced Oil Recovery Institute (EORI) and the Institute of Scientific Computation (ISC) at the University of Wyoming. During his stay in Laramie in 1988–1992, Lazarov worked on superconvergence and local refinement techniques for mixed FE methods. During that time Raytcho initiated many collaborations and friendships with prominent mathematicians such as Jim Bramble, Joe Pasciak, Panayot Vassilevski, Junping Wang, Tom Russell, Yuri Kuznetsov, Steve McCormick, Tom Manteuffel, and Owe Axelsson. At that time Raytcho Lazarov led the development of algorithms based on the Bramble–Ewing–Pasciak–Schatz (BEPS) preconditioner and locally refined mixed FE and finite-volume methods that were also implemented in the EORI proprietary codes.

The friendship and collaboration with Dick Ewing initiated another change in Raytcho's career, and in 1992 he moved to Texas A&M University as a professor of mathematics, a position that he continues to hold now. This coincided with the establishment of the Institute of Scientific Computation (ISC) at Texas A&M under the directorship of Richard Ewing, which quickly attracted a team of world-renowned experts in this area like J. Bramble, J. Pasciak, R. Lazarov, and, more recently, Y. Efendiev, J.-L. Guermond, G. Petrova, B. Popov, W. Bangerth, and A. Bonito. The work they did in the last 20 years on computational mathematics and its applications in flows in porous media, multiphysics problems, modeling of fluids, structures and their interactions, etc. had a significant impact on these and in other research areas. Raytcho's pivotal role in this research is well known from his results on least-squares FEM; discontinuous Galerkin methods; multigrid, multilevel, and multiscale methods, mixed FEM, and more recently fractional order partial differential equations.

In recognition of his achievements Raytcho Lazarov has been awarded several honorary titles and degrees: the medal "St. Kl. Ohridski" with blue ribbon (2003—the highest honors given by Sofia University, Bulgaria, to scientists); Doctor Honoris

Causa of Sofia University “St. Kl. Ohridski” (2006); the medal of the Institute of Mathematics, Bulgarian Academy of Sciences 2008; Pichoridis Distinguished Lectureship, University of Crete, Greece (2008); and Erasmus Mundus Visiting Scholar Award, University of Kaiserslautern (2008). Most recently he was named a recipient of the medal of the Bulgarian Academy of Sciences “Marin Drinov” with ribbon (2013), which is given to scholars for outstanding contributions in the advancement of science.

During his career Lazarov has held visiting positions and contributed to advancement of research in many institutions around the globe: Joint Institute for Nuclear Research in Dubna, Russia (1980); Australian National University, Canberra (1990); Mittag Leffler Institute of Mathematics, Stockholm, Sweden (1998); University of Linz and RICAM, Austria (2005); Fraunhofer Institute of Industrial Mathematics, Kaiserslautern, Germany (2006); Lawrence Livermore National Laboratory (regularly from 1998 to 2010); and KAUST in Saudi Arabia (2008–2013). He is a member of the editorial board of five international journals and a number of conference proceedings, and he is also serving on the scientific committees of several international conferences.

Raytcho Lazarov is an outstanding scholar, and his work has had a profound impact on mathematics and other fields of science and engineering during the last four decades. His extraordinary personality, with strict academic integrity requirements for himself and his collaborators complemented by truly compassionate care about their needs, has influenced the professional and personal development of those who have had a chance to work with him. The teams which he has created over the years combined research interests, philosophy, and personal friendship, and they withstood the test of time.

We congratulate Raytcho on the occasion of his 70th birthday and wish him the best of health and enjoyment in his personal life and in continuing and expanding his successful research achievements.

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<http://www.springer.com/978-1-4614-7171-4>

Numerical Solution of Partial Differential Equations:  
Theory, Algorithms, and Their Applications  
In Honor of Professor Raytcho Lazarov's 40 Years of  
Research in Computational Methods and Applied  
Mathematics

Iliev, O.P.; Margenov, S.; Minev, P.D.; Vassilevski, P.S.;  
Zikatanov, L.T. (Eds.)

2013, XII, 327 p., Hardcover

ISBN: 978-1-4614-7171-4