Preface for Volume II: Inverse Problems and Large-Scale Computations

In this volume we collected some of the articles presented on the Second Annual Workshop on Inverse Problems and works presented at the Workshop on Large-Scale Modeling. Both workshops were supported by the Swedish Institute, Visby program and co-organized by the Department of Mathematical Sciences, Chalmers University of Technology and University of Gothenburg and Karlstad University and took place from May 1 to 6, 2012, in Sunne, Sweden.

All papers in this volume highlight the most recent findings in new solution techniques for the inverse problems, analysis of wave propagation in nonlinear media, and some other research areas. The numerical and mathematical methods are developed for powerful supercomputers employing parallel computations and applicable for solving large-scale problems and very large equation systems. The book is maybe the first attempt to unite rigorous mathematical statements and methods and the most advanced to date numerical techniques and algorithms aimed at solution to large-scale problems with an account of uncertain data. The first three papers of this book reflect topics presented at the Second Annual Workshop on Inverse Problems. Construction of new reliable methods for solution of coefficient inverse problems is a very challenging task. An adaptive approximately globally convergent method for a hyperbolic coefficient inverse problem in the case of backscattering data is studied in the paper by M. Asadzadeh and L. Beilina. In this paper authors present also numerical examples for reconstruction of land mines from backscattered data using an adaptive approximate globally convergent algorithm. A mathematical formulation of a coefficient inverse problem and a procedure on how to find the distribution of electrical conductivity and magnetic permeability in the isotropic geological medium from the frequency domain measurements is reported in the paper by V. Gubatenko. A new approximate globally convergent method for the reconstruction of an unknown conductivity function from backscattered electric field measured at the boundary of geological medium under assumptions that dielectric permittivity and magnetic permeability are known functions is developed in the paper by J.B. Malmberg and L. Beilina. Authors presented their method for the typical case of a coefficient inverse problem arising in electrical prospecting.

The remaining papers of this volume reflects variety of subjects discussed on the Workshop on Large-Scale Modeling. One of them is the development of models based on self-consistent statement of propagation, resonance scattering, and generation of waves in nonlinear layered dielectrics, including elaboration and comparison of different numerical algorithms for simulating the field effects at multiple frequencies on the wave scattering and generation. These results are important for creating nonlinear dielectrics with controllable permittivity and various applications in device technology and electronics. The studies are performed by L. Angermann, V. Yatsyk, and D. Valovik. Implementation of the algorithms and techniques developed for the analysis of nonlinear problems using high-performance multi-core and multiprocessor computers is reported in the paper by V. Trofimov, O. Matusevich, I. Shirokov, and M. Fedotov. A. Smirnov with coauthors developed the methods and algorithms that can be used for a wide class of forward problems of electromagnetic field theory when numerical solution by conventional FDTD methods met substantial difficulties due to complex geometries or computational requirements. The solver created on the basis of the proposed approach employs algorithms of parallel computations and is implemented on supercomputers of last generation for solving large-scale problems with characteristic matrix dimensions achieving 1012. Modern analytical and numerical approaches in optical waveguide theory employing spectral theory of operator-valued functions and the integral equation method are considered in the paper by A. Frolov and E. Kartchevskiy. Linear with respect to observations, optimal estimates of solutions and right-hand sides of Maxwell equations with uncertain data (called minimax or guaranteed estimates) are studied by Y. Podlipenko and Y. Shestopalov. The methods for finding these estimates are proposed, estimation errors expressed in terms of solutions to special variational equations are obtained, and the convergence of Galerkin approximations is proved. Development of efficient analytical and numerical solution techniques for the inverse problems occupies a special place in the book. In fact, the determination of electromagnetic parameters of dielectric bodies of complicated structure is an urgent problem because these parameters cannot be directly measured (due to composite character of the material and small size of samples), which leads to the necessity of applying methods of mathematical modeling and numerical solution of the corresponding forward and inverse electromagnetic problems. It is especially important to develop the solution techniques when the inverse problem for bodies of complicated shape is considered in the resonance frequency range. In the paper by Y. Smirnov, Y. Shestopalov, and E. Derevyanchuk a method is developed for the solution to the inverse problem of reconstructing (complex) permittivity of layered dielectrics in a waveguide from the transmission coefficients measured at different frequencies. The method enables in particular solutions in a closed form for one- and multi-sectional diaphragms. Numerical results of calculating (complex) permittivity of the layers are presented and the case of metamaterials is also considered. The results can be applied in nanotechnology, optics, and design of microwave devices. The paper by A. Samokhina and E. Trahtengerts is of special value as far as identification and analysis of large-scale problems with uncertain data in different areas of science and technology are concerned. The authors consider the algorithms of facilitating the decision-making process when simultaneous or almost simultaneous emergencies take place. In the presence of huge volumes of incoming information effective algorithms of emergency identification are proposed and developed for the analysis and solution of corresponding large-scale problems. The issues related to dynamic computer support are also examined in the paper. Among the book features it should be noted that in many articles a reader finds the whole description of the approach, from the accurate problem statement to numerical results obtained using most powerful to date computer resources and facilities. The intended audience of the book is: university students (knowledge of mathematics: bachelor level and higher), PhD students (specializing in applied mathematics, mathematics, electrical engineering, physics), Dr Sci, researchers, university teachers, RD engineers, and electrical engineers with deeper knowledge and interest in mathematics.

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