

The IMA Volumes in Mathematics and its Applications

Volume 163

Series editor

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Daniel Spirn, Director of the IMA

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Frontiers in PDE-Constrained Optimization

 Springer

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Foreword

This volume contains a series of papers based on a workshop “Frontiers in PDE-Constrained Optimization” held at the Institute for Mathematics and its Applications from June 6 to 10, 2016, and organized by Harbir Antil, Drew Kouri, Martin Lacasse, and Denis Ridzal. This workshop drew together a cohort of scientists working in PDE-constrained optimization in a variety of disciplines, ranging from medical imaging to geosciences. The collection of works in this volume reflects this diversity of application and documents the recent mathematical and computational advances in the field. We would like to especially thank the workshop organizers, who have served as the editors of this volume. Finally, we acknowledge ExxonMobil, which provided funding for the workshop, and the National Science Foundation for its support of the IMA.

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Preface

Many science and engineering applications necessitate the solution of optimization problems constrained by physical laws that are described by systems of partial differential equations (PDEs). As a result, PDE-constrained optimization problems arise in a variety of disciplines including geo-physics, earth and climate science, material science, chemical and mechanical engineering, medical imaging, and physics. The goal of this volume is to provide a broad and uniform introduction of PDE-constrained optimization as well as to document a number of interesting and challenging applications.

This volume contains the proceedings of the workshop “Frontiers in PDE-Constrained Optimization” held at the Institute for Mathematics and its Applications from June 6 to 10, 2016. The workshop successfully provided a common forum for networking between leaders in PDE-constrained optimization within academia, industry, and the US national labs. The five-day workshop included two days of tutorials and three days of invited talks. The tutorials were targeted toward students and researchers interested in entering the field of PDE-constrained optimization and provided an overview of the field with special emphasis on uncertainty, variational inequalities, shape optimization, inverse problems, algorithmic development, and software implementation. The invited presentations disseminated cutting-edge developments in theory, numerics, and applications.

This volume is divided into two parts. The first part provides a comprehensive review of modern topics in PDE-constrained optimization. Chapter “A Brief Introduction to PDE Constrained Optimization” provides a basic introduction to PDE-constrained optimization. Chapter “Optimization of PDEs with Uncertain Inputs” discusses optimization problems constrained by PDEs with uncertain or random inputs. Chapter “Inexact Trust-Region Methods for PDE-Constrained Optimization” focuses on the efficient numerical solution of PDE-constrained optimization problems using inexact trust-region methods. Chapter “Numerical Optimization Methods for the Optimal Control of Elliptic Variational Inequalities” provides a theoretical and numerical overview of optimization problems constrained by elliptic variational inequalities. Chapters “Introduction to PDE-Constrained Optimization

in the Oil and Gas Industry” and “Full-Wavefield Inversion: An Extreme-Scale PDE-Constrained Optimization Problem” describe a variety of theoretically and computationally challenging inverse problems arising in the oil and gas industry. Chapters 1–6 are organized in such a way that they can be used as a reference to augment a graduate course in PDE-constrained optimization.

The second part of this volume focuses on applications of PDE-constrained optimization. Chapters “Energetically Optimal Flapping Wing Motions via Adjoint-Based Optimization and High-Order Discretizations” and “Optimization of a Fractional Differential Equation” consider PDE-constrained optimal control with applications to flapping wing machines and anomalous diffusion. Chapter “Sensitivity-Based Topology and Shape Optimization with Application to Electric Motors” discusses a sensitivity-based approach for optimal design via topology and shape optimization. Chapter “Distributed Parameter Estimation for the Time-Dependent Radiative Transfer Equation” discusses the parameter estimation in time-dependent radiative transfer equations. Following this, Chapter “On the Use of Optimal Transport Distances for a PDE-Constrained Optimization Problem in Seismic Imaging” discusses the use of optimal transport distances in seismic imaging. To conclude the volume, Chapter “Exploiting Sparsity in Solving PDE-Constrained Inverse Problems: Application to Subsurface Flow Model Calibration” describes the role of sparsity in inverse problems with applications to subsurface flow model calibration.

Acknowledgement As organizers and editors, we would like to acknowledge ExxonMobil, which provided funding for the workshop, and National Science Foundation for its support of the IMA. We are further indebted to the former and current IMA directors Fadir Santosa and Daniel Sporn for encouraging this initiative, as well as to Danielle Walker (Springer) for her help in putting together this volume.

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