Inverse Problems

PREFACE

Foreword to special issue of *Inverse Problems* on modern challenges in imaging

To cite this article: Bernadette N Hahn *et al* 2023 *Inverse Problems* **39** 030401

IOP Publishing Inverse Problems

Inverse Problems **39** (2023) 030401 (4pp) https://doi.org/10.1088/1361-6420/acb569

Preface

Forward to special issue of *Inverse Problems* on modern challenges in imaging

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Received 12 January 2023
Accepted for publication 23 January 2023
Published 3 February 2023

This special issue of *Inverse Problems* honours the achievements of Nobel Laureate Allan Cormack (1924–1998) whose pioneering work provided mathematical foundations of computerized tomography. It gathers top articles on inverse problems in imaging, including a broad range of tomographic modalities, mathematics, and applications. Inverse problems, typically image reconstruction from indirect data, now play a crucial role in many aspects of human life such as healthcare, national security, non-destructive testing, and remote sensing. The relentless progress in imaging technology opens myriad possibilities, pushes researchers to overcome new theoretical and practical challenges, and has an enormous impact on everyday life. Twenty-nine high-quality original research papers have been collected in this special issue. They represent a broad range of inverse problems, from theoretical and computational perspectives, and are all related to modern challenges in imaging.

Most inverse problems involved in physical processes are ill-posed, requiring suitable regularization schemes to stabilize the inverse and the reconstruction process. The emergence of numerous novel applications as well as the evolution of constraints such as costs, time, access, etc and hence the need for more efficient, smaller, and cheaper systems, lead to new challenges in terms of regularization and reconstruction schemes. This special issue offers many answers to these challenges. [19] provides a deep and fresh look at ℓ_1 Tikhonov regularization. [13] adapts the ADMM method for total-variation myopic deconvolution. [3] proposes bilevel optimization neural networks based on the fractional Laplacian to solve inverse problems. [17] also addresses the question of edge-preserving regularization method and works out an inner-outer approach that improves Tikhonov regularization by constructing adaptive smoothing operators. [11] studies ℓ_p-ℓ_q constrained minimization problems and develops associated modulus-based iterative schemes. In [23], the authors develop the theory of Bayesian

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sensing for hyperparameter estimation and use this framework to reconstruct in travel time seismic tomography and imaging deblurring. Image reconstruction in dynamic computerized tomography is addressed in [10] with a sparse setup and using shearlet decomposition while [8] deals with the model inexactness induced by the unknown motion using and studying the RESESOP algorithm. [18] uses compressed sensing to estimate parameters in two-photon photo-acoustic tomography (PAT). [28] explores progress on Calderón's method with applications to electric impedance tomography (EIT), while [1] establishes a modified forward and inverse model for EIT and inverse scattering problem for diffuse waves. Finally, many inverse problems can possess more than one parameter. In that case, the concept of joint reconstruction has flourished, for instance in PAT [24] and single photon emission CT [25].

After developing a realistic model for each inverse problem or imaging modality, one must develop proper discretizations of the model and data to fit real measurements. For instance, [7] performs the numerical analysis of filtered back-projection (FBP)-type algorithms, analyzing the induced error with respect to Besov spaces. [6] offers a deep analysis of the phase retrieval problem. And [15] considers a new model for acousto-optic tomography while [2] studies generalized V-line transforms involved in vector tomography. Finally [21] derives a rich analysis of the resolution and contrast in CT working with distributions.

Constant technological progress leads engineers and mathematicians to develop new applications from new imaging modalities. For instance, the recent development of energy-resolved cameras (e.g. using scintillation crystals) offers a new variable to explore: the energy. In particular, the Compton effect represents a dominant physical phenomenon when working with x- and γ-rays. This effect can be exploited through the so-called Compton scattering tomography (CST). Two modalities in CST are studied in [12] via harmonic analysis and in [29] in terms of microlocal analysis. In [26], the Compton spectrum (including the second-order scattering) is studied and approximated by Fourier integral operators leading to FBP-type reconstruction strategies for the extraction of contours.

Inverse problems also cover many new fields such as the study of atmospheric phenomena, see [20], or the extraction of elastic properties using optical coherence tomography, see [27] which proposes to estimate the internal displacement field of the object under study. Magnetic particle imaging (MPI) is a new topic of research for many research groups motivated by the well-established modality of MRI. [9] establishes a new model for 3D MPI. Also, [22] develops a super-resolution strategy combined with a parameter identification for MPI.

Finally, the rise of big data with large feature spaces has quickly become a focus of research in applied mathematics, and the fields of inverse problems and imaging are no exception. [14] studies an extension of the generalized Golub-Kahan bidiagonalization when considering stochastic priors on large-scale inverse problems. [16] deals with the problem of sampling and memory for large-scale inverse problems. Deep learning is also exploited in [5] for homeland security and in [4] for standard CT using deep priors.

This collection of articles illustrates the breadth and depth of the field, and it is an appropriate tribute to the memory of Professor Cormack and his seminal work in tomography.

Data availability statement

No new data were created or analysed in this study.

Acknowledgment

The editors thank the U.S. National Science Foundation for Grant DMS-1906664 National Institutes of Health for Grant 1R13EB028700-01, Tufts University, and private donors for their support of the conference "Modern Challenges in Imaging in the Footsteps of Allan Cormack" that motivated this special issue. We thank Inverse Problems for their excellent support in producing this special issue.

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