PHOTONICS INSIGHTS

Image reconstruction from photoacoustic projections

Alexander A. Oraevsky*
TomoWave Laboratories, Inc, Houston, USA

Thirty years ago, we demonstrated laser-based depth-resolved optoacoustic imaging of biological tissues[1–3], laying an important foundation for modern optoacoustic tomography (OAT) alternatively called photoacoustic computer tomography (PACT). Today, OAT/PACT has become one of the fastest-growing biomedical imaging technologies and has found a wide range of applications in biomedicine[4,5]. Complementary to anatomical imaging of tissue structures with ultrasound, X-rays, and radiofrequency waves, OAT/PACT is a molecular imaging technology that employs diffused light absorbed by molecules in biological tissues and generates ultrasound signals resulting from thermal expansion of instantaneously heated tissue voxels. It uniquely visualizes endogenous tissue chromophores of hemoglobin and oxyhemoglobin, as well as nontoxic exogeneous chromophores of dyes and nanoparticles, and achieves imaging resolution of hundreds of microns at 3–5-cm depth in biological tissues[6].

Analogous to other types of computed tomography, image formation in OAT relies on sophisticated image reconstruction algorithms[7], without which details in an image may not be properly resolved, and quantitative accuracy of the optoacoustic contrast may be lost. The recently published review article[8] by Tian *et al*. provides a thorough overview of the developments of the image reconstruction algorithms over the past three decades.

It starts from the forward problem of OAT/PACT and introduces the principle of key algorithms with intuitive examples. Major topics, important concepts, term abbreviations, and mathematical symbols are illustrated or summarized using figures or tables.

In the review article, the authors first reviewed the forward problem of OAT/PACT from the perspectives of signal generation, signal propagation, signal detection, and the Radon transform. They next summarized key conventional image reconstruction algorithms, such as delay and sum, filtered back projection, series expansion, time reversal, and iterative methods of image reconstruction. Then, the authors surveyed major deep-learning-based image reconstruction strategies, including signal preprocessing in the data domain, image postprocessing in the image domain, hybrid-domain processing, direct signal-to-image reconstruction, and iterative reconstruction learning. After that, the authors compared the performance of different image reconstruction algorithms under various imaging scenarios, such as limited-view imaging, sparse-view imaging, and imaging in acoustically heterogeneous media. They finally discussed major challenges in OAT/PACT image reconstruction and future research directions. The review cites over 300 references, and compiles and critiques decades of research in a manner that is both comprehensive and comprehensible.

The review excels in the following two aspects: depth of analysis and comprehensiveness. While focusing on an in-depth analysis of conventional image reconstruction algorithms such as delay and sum, filtered back projection, series expansion, and time reversal, the review also covers emerging deep-learning-based algorithms, highlighting iterative reconstruction methods representing the latest developments in the field. Notably, this review contains in-depth comparative studies. Major image reconstruction algorithms were coded and evaluated in terms of image reconstruction quality, reconstruction speed, and memory footprint via specific examples. The comparative studies can help readers better understand the strengths and weaknesses of each algorithm. The review is comprehensible, so all researchers in the field of OAT/PACT including beginners can understand and use it in their work.

Overall, the review by Tian *et al*. provides an excellent discussion of OAT/PACT image reconstruction algorithms, from conventional to machine learning. It can help general readers to better understand the field and, thus, promote the development and application of novel algorithms in optoacoustic/photoacoustic/thermoacoustic tomography.

References

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*Address all correspondence to Alexander A. Oraevsky, ao@tomowave.com

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