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Editorial: Advances in image formation methods for optoacoustic and ultrasound imaging

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Editorial on the Research Topic
Advances in image formation methods for optoacoustic and ultrasound imaging

Optoacoustic (OA, photoacoustic) and ultrasound (US) imaging capitalize on the low scattering of acoustic waves within biological tissues to provide high-resolution images of deep-seated structures in a fully non-invasive manner. The optical contrast mechanism of OA imaging enables resolving endogenous chromophores like hemoglobin, melanin, lipids, collagen and water Deán-Ben X.L et al. 2017. On the other hand, US imaging methods exploit different types of contrast mechanisms to visualize acoustic scattering, speed of sound, acoustic attenuation as well as blood flow [2]. The complementary advantages of OA and US represent a powerful tool to interrogate healthy and diseased tissues. Indeed, most advanced clinical systems combine US and OA imaging technology and are at the brink of clinical translation. A correct approach to the inverse (image formation) problems in OA and US imaging is essential for an optimal performance. This Research Topic summarizes recent advances in image formation methods for OA and US imaging and new imaging capabilities enabled with these.

The research article contributed by Chintada et al. proposes a new US-based approach for mapping the speed of sound and frequency-dependent acoustic attenuation in heterogeneous biological tissues. These two parameters provide a powerful means of characterizing the pathology and structure of the tissues being examined [3]. For example, the speed of sound is known to be higher in tumors than in normal tissues in the liver and other organs [4]. Acoustic attenuation maps are also useful to identify neoplastic lessions [3]. The method proposed in the original article of Chintada et al. is based on Fourier-domain analysis of the reflections from an acoustic mirror positioned at a known distance from an US array operating in pulse-echo mode. Reconstruction of speed of sound and attenuation maps was achieved *via* iterative inversion of a linear model considering a power-law dependent attenuation. The good performance of the new method was demonstrated in tissue-mimicking phantoms consisting of a gelatin-cellulose mixture and *ex-vivo* bovine muscle samples.

The research article contributed by Lee et al. presents a new method for compensating for breathing-related artefacts in US and OA images acquired with a single-element transducer. Hybrid OA-US imaging is often performed to exploit the synergistic advantages of both modalities [5–7]. In particular, while pulse-echo US imaging provides a well-established anatomical references, OA imaging facilitates functional imaging of vascular networks and molecular imaging of biological processes at the cellular and subcellular levels. Lee et al. used a spherically-focused US transducer raster-scanned across the sample to visualize internal structures in mice. The US images enabled identifying the mouse skin, and the distorted skin layers were accordingly compensated. The distortion parameters were then used to compensate for the motion in OA images. The performance of the new method was demonstrated by visualizing oxygen saturation of hemoglobin in three-dimensions in the entire body of a mouse based on multi-spectral OA data.

The research article contributed by Chandramoorthi et al. suggests a new method combining transducer arrays with different detection bandwidth for enhancing the accuracy of OA images. OA excitation is generally performed with short-pulsed lasers, which result in broadband signals with spectral components determined by the size and shape of internal structures [8, 9]. In practice, the bandwidth of the collected signals is determined by the frequency response of the transducer(s) employed [10], and can be enhanced by combining the acquired signals from multiple transducers with different responses. This combination is however hampered by the fact that different transducers differ in sensitivity, which may result in misinterpretation OA signal strengths. Chandramoorthi et al. developed a novel method for the calibration of the relative sensitivities of the two transducer arrays employed. An enhanced OA imaging performance was first demonstrated in wire targets and subsequently in bovine tissue samples and human blood vessels. In the last two samples, pulse-echo US imaging was also performed to provide an anatomical reference.

Finally, the review article contributed by Dean-Ben and Razansky provides a practical guide for model-based OA reconstruction in different types of systems. Model-based reconstruction methods have been shown to outperform alternative approaches and can further render OA images from incomplete datasets, strongly distorted signals or in other challenging conditions [11–14]. Modelling in OA imaging is facilitated by the fact that the excitation of OA responses and subsequent propagation of US waves can be mathematically described. This enables building a forward model enabling image reconstruction *via* model-based (iterative) inversion. The review article by Dean-Ben and Razansky systematically covered this Research Topic in a practical manner, focusing on the achievable performance in practical cases rather than on the mathematical details of the algorithms. The forward and inverse problems are first described and the performance of model-based and standard back-projection algorithms is compared. Subsequently, the capability of model-based algorithms to account for the response of the transducer(s) employed and acoustic propagation effects is described. Compressed acquisition and reconstruction schemes are finally described before providing an overall perspective and future directions.

The innovative methods in this Research Topic manifest the importance of image formation methods in OA and US imaging and illustrate the strong momentum of new methodologies in both modalities. It is anticipated that future advances in OA and US imaging will strongly rely on new image reconstruction and processing algorithms to be developed in parallel with new embodiments and hardware components. Overall, proper approaches of the inverse problem associated to OA and US image formation are essential to achieve an optimal performance and enable new preclinical and clinical applications.

Author contributions

XLD-B wrote the editorial.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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