A photoacoustic-ultrasound transmission breast tomography system: system overview and first imaging results

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We present a hybrid photoacoustic-ultrasound (PA-US) tomographic imaging system, developed within the European consortium PAMMOTH [1]. The system employs a hemispherical geometry with an imaging bowl filled with water into which the breast is positioned. The bowl has 512 ultrasound transducers distributed on its inside surface. Forty optical fibre bundles terminate at the inner surface of the bowl, distributed to illuminate the breast homogenously for photoacoustic excitation. At the proximal end, the fibre bundles are brought together and coupled to a dual laser-OPO system providing 5 nanosecond pulses in the wavelength range 680 - 1060 nm. In addition to functioning in reception mode for photoacoustic imaging, the transducers can be used in emission mode for ultrasound transmission imaging. During a measurement, the imaging bowl and its contents rotate around the breast, which is immobilized in a transparent cup, to acquire multiple projections. Photoacoustic reconstruction is performed using a full-wave inversion model; sound speed images are reconstructed using a bent-ray approach from transmission ultrasound data [2].

To unravel an optimal measurement sequence, in which optimized imaging performances are achieved within as short as possible measurement times, systematic tests were performed on test objects [3], a breast mimicking phantom [4] and healthy volunteers. We present the approach we followed to optimize the optimal measurement sequence of our system. Here, systematic tests on a test objects with sub-resolution PA sources allowed us to investigate the effect of the number of measurement projections and averages on the spatial resolution and signal-to-noise ratio. Multispectral PA measurements on a blood carrying breast phantom (as well as on healthy breasts) helped us to select the optimal excitation wavelengths for accurate oxygen saturation estimations and large imaging depths. With US transmission measurements on another test object we assessed the accuracy of our system in measuring sound speed distributions. The same measurements in-vivo resulted in sound speeds matching breast tissues, which improves the PA imaging performance in the deep breast when applied in the PA inversion models.

We conclude by demonstrating the functionalities of the imaging system and its imaging capability on healthy volunteers. From the multispectral photoacoustic (PA) mode, we obtain angiographic breast structures in 3D throughout the breast, and provide a measure for the blood oxygen saturation. From the ultrasound (US) mode, the sound speed images serve to improve the accuracy of the PA reconstruction, and also provide morphological information which helps interpretation of the PA images. We touch upon future studies that we aim perform using this system.

References

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