Frontiers in Optics + Laser Science (FiO/LS) @ Optica Publishing Group 2022

Deep-learning-enhanced Three-dimensional Photoacoustic Tomography of Human Breast

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Abstract: We developed a fully-dense neural network to improve the elevation resolution of linear-array-based photoacoustic tomography for better 3D visualization. The algorithm is efficient and fast and is validated in human breast imaging results.

1. Introduction

Photoacoustic computed tomography (PACT) is a hybrid biomedical imaging modality that combines the merits of high optical absorption contrast and high acoustic resolution. Among different types of transducers, linear transducer arrays are widely used due to their handheld convenience and low cost. Linear-array-based photoacoustic tomography has shown broad applications in biomedical research and preclinical imaging. The 3D resolution of a linear array is defined along with lateral, axial, and elevational directions. The elevational direction is perpendicular to the lateral and axial plane, and a linear array can be scanned in this direction to form a 3D image. However, the elevational resolution is poor due to the large transducer element height and the weak cylindrical focus. Here, we propose a deep learning-based method to improve the elevational resolution in PACT and compare the deep learning results with conventional 2D reconstruction and 3D focal line reconstruction[1].

2. Method

In this study, we provide an efficient simulation approach to generate poor elevational resolution training data. The simulation method is demonstrated in Fig.1. An arc-shaped transducer detects the A-line signal along the axial direction. The arc-shaped transducer is assumed to move along the elevational direction to mimic the elevation scanning with a step size of 0.1 mm. Then, the B-scan image is formed in the axial-elevation plane by stacking all the A-lines in sequence. When all the B-scan images are stacked along the lateral direction, the 3D PACT image is formed. We used this simulated B-scan data to train a deep learning model for elevation resolution enhancement. The model using our unique training data is named Deep-E, a fully dense neural network based on U-net [2].

3. Results

Fig.2 shows the deep learning validation result on human breast data. The breast imaging protocol is described in [3]. The result in Fig. 2(a) shows that Deep-E can recover vascular structures much better than 2D-stack and 3DFL. It not only refines the vessel resolution but also reveals deeper vessels. For better illustration, we also plotted the cross-sectional images (Fig. 2(b)) taken across the orange-marked line in the images of Fig. 2(a). Our results indicate that Deep-E can be successfully applied to in vivo experimental data, even if the vascular structures are dense and complicated.

4. Conclusion

Deep-E exhibits high computational efficiency by converting the three-dimensional problem into a two-dimension problem: it focused on training a model to enhance the resolution along the elevational direction by only using the 2D slices in the axial and elevational plane [2]. To the best of our knowledge, this is the first study that uses deep learning to improve 3D human breast data in PACT.

5. Figures

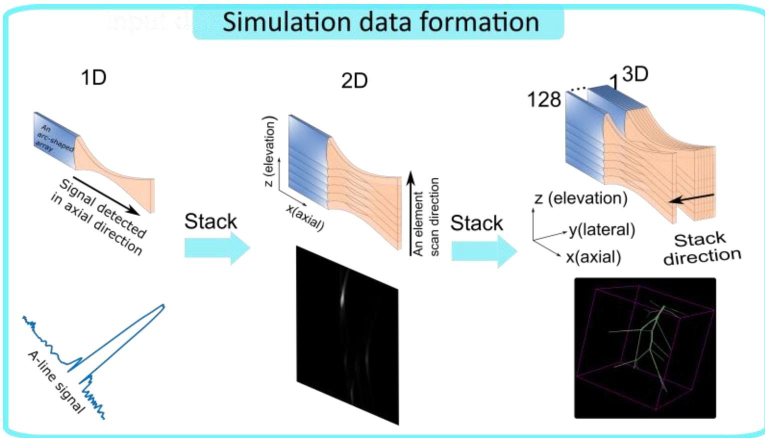

Fig. 1. Simulation method to generate photoacoustic data with poor elevation resolution.

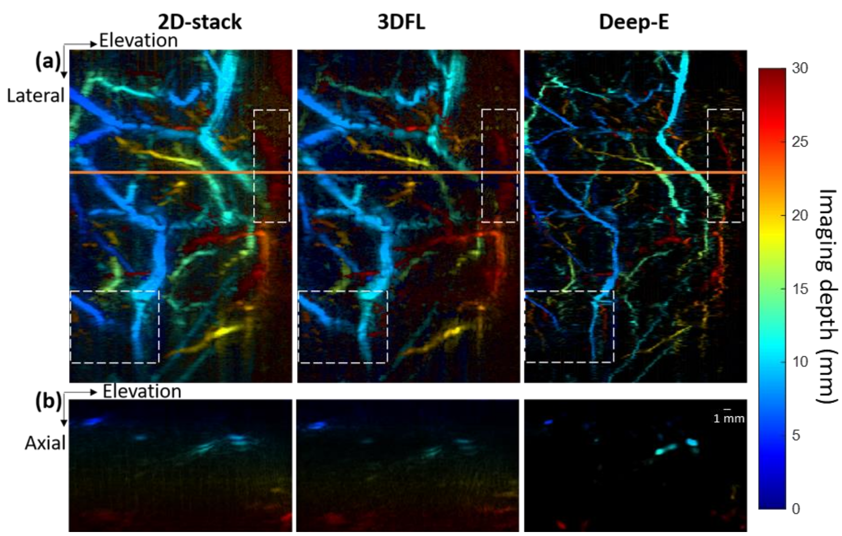

Fig. 2. Photoacoustic breast data reconstructed using different algorithms. (a) the reconstructed depth-encoded MAP breast image. (b) cross-sectional breast images taken along the orange line in (a).

6. References

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