Experimental evaluation of a 3-D fully convolutional network for learning blood oxygenation saturation using photoacoustic imaging

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Background, Motivation and Objective

Estimating blood oxygen saturation (sO_2) using spectroscopic photoacoustic imaging has long been proffered as a technique that could overcome the limitations of existing methods. In this work, a 3D convolutional neural network which was trained using simulated data only has been assessed for the purpose of estimating surrogate sO_2 from multiwavelength photoacoustic images of experimental phantoms with well-defined ground truths. By testing the network with experimental data, a first indication of the extent to which a network trained on simulated images alone can be applied to measured data and yield accurate sO_2 estimates can be obtained. This will guide the development of future learned sO_2 estimation strategies.

Statement of Contribution/Methods

The learned approach used in this study employs a convolutional encoder-decoder with skip connections that was trained to output the sO_2 distribution from a multiwavelength photoacoustic image data set [C. Bench, JBO, 2020]. The simulated training image data set was generated using a source model which defines the spatial distribution of optical coefficients in the phantom, a numerical forward photoacoustic model and an image reconstruction algorithm.

To obtain measured test data with a reliable ground truth, a phantom comprising 4 tubes containing aqueous solutions of $NiSO_4$ and $CuSO_4$ which serve as analogues for oxy and deoxyhaemoglobin immersed in Intralipid was used (Figure 1(a)). By adjusting the ratio of the $NiSO_4$ and $CuSO_4$ concentrations [M. Fonseca, *JBO*, 2017] (Q ratio), the surrogate "sO2" values of solution in the tubes was varied. The phantom was illuminated with pulsed laser light at different wavelengths between 700 and 900nm and the resulting photoacoustic waves mapped in 2D over a 12 x 12 mm aperture using a planar Fabry Perot scanner. 3D images were reconstructed using time-reversal.

Results/Discussion

By randomly varying the positions, diameters and Q ratios of the 4 tubes a set of simulated multiwavelength photoacoustic were generated and used to train the network. The network was then tested using (i) simulated data generated from source models not used in the training data set and (ii) the experimental datasets. Figure 1(b) shows the steps for the generation of training data. Figure 1(c) shows that the predicted Q ratio in each tube agrees with the ground truth for the simulated test data. The same comparison for the experimental test data (Figure 1(d)) reveals reasonable agreement for only 2 of the four tubes however. This work provides a first demonstration indication of the extent to which simulated-only data trained networks can be expected to provide accurate sO_2 estimates.

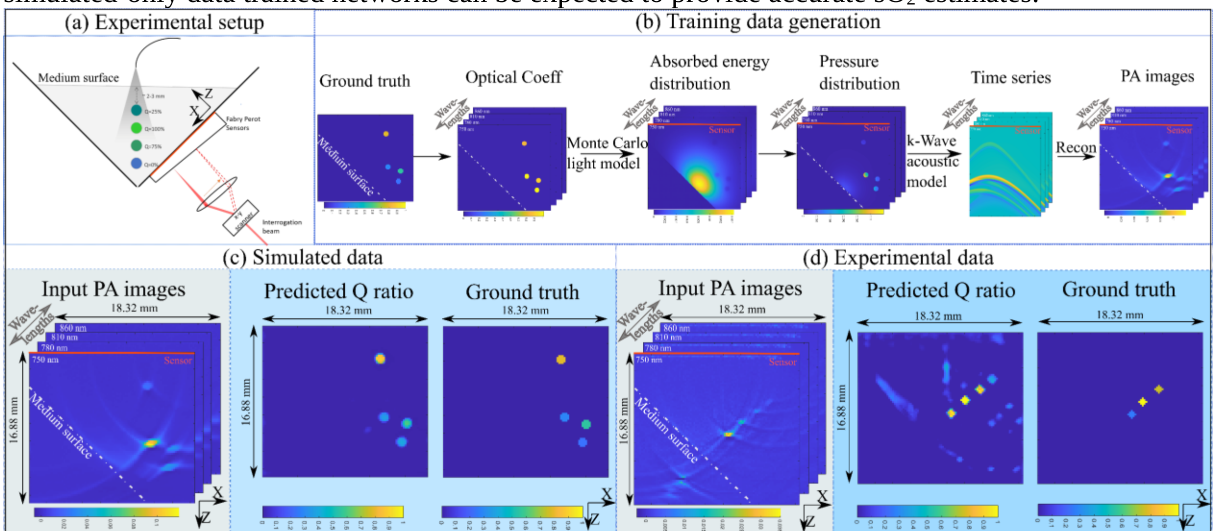

Figure 1: (a) Experimental setup (b) Steps of training data generation (c) X-Y projection of the predicted Q ratio distribution and the corresponding ground truth from simulated data (d) X-Y projection of the predicted Q ratio distribution from experimental data. Q ratio is a surrogate for sO2.