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Learned Regularization for Iterative Photoacoustic Reconstruction

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***Abstract*—Recently, deep learning methods have shown great potential in photoacoustic imaging. In this work a specific network structure is designed to learn the regularize term of traditional iteration method reconstruction. The performance of this method is tested on simulation dataset for sparse view condition.**

***Clinical Relevance*— This method will help improving imaging speed and imaging quality of photoacoustic imaging.**

I. Introduction

Photoacoustic (PA) imaging is capable of visualizing the optical absorption of biological tissues. It is showed that iterative image reconstruction methods that minimize a penalty function can provide high quality reconstruction images but suffer from high computational complexity and difficulty of designing specific penalty term. While deep learning methods can learn information directly from raw data, they usually give up the well-established physics models used in reconstruction process, which leads to heavily depending on data distribution. In this paper, we design a iterative deep learning scheme that combine data based deep learning method with model based iterative model.

II. Methods

The reconstruction of PA imaging can be performed iteratively by applying gradient decent method, the updating strategy from step k to step $k+1$ is shown in (1):

$$\boldsymbol{x}^{k+1}=\boldsymbol{x}^{k}-\lambda A^{T}(A\boldsymbol{x}^{k}-y)-R_{CNN}, \quad (1)$$

in which $\boldsymbol{x}$ is the initial wave, A is the system matrix representing the propagation and measurement of the PA signal, R_{CNN} is the gradient of regularize term learned by deep learning network.The designed network is based on gradient decent scheme, as shown in Fig.1.

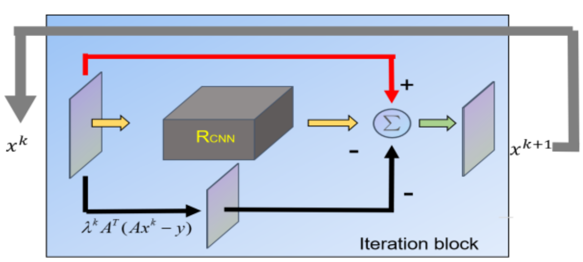

Figure 1. Network structure

The network is trained iteratively, which go through just single iteration step to optimize every step $\boldsymbol{x}^k$ separately. The phantom used for simulation is human fundus image dataset which is augmented to the number of 1000 by clipping and rotating [1]. The PA signal is simulated using k-wave toolbox [2], using ring transducer with diameter of 50mm.

III. Results

The reconstruction results of iteration method and deep learning method is shown in Fig.2. Phantom image is used as reference image. Signals of 32 elements are used for sparse reconstruction. The SSIM value of iteration result is 0.514, while SSIM of deep learning result is 0.961. The result suggests that the proposed deep learning method can produce better result than tradition iteration method under sparse view condition.

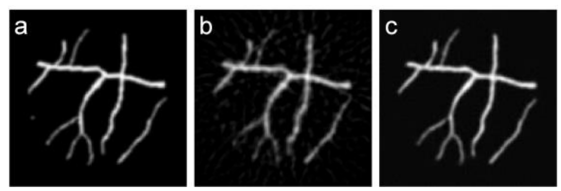

Figure 2. Reconstruction results. (a) reference image; (b) traditional iterative reconstruction; (c) deep learning reconstruction.

IV. Discussion & Conclusion

This work provides an idea of combining deep learning methods and traditional reconstruction methods, which benefits from both data distribution and well-established physic models. The form of CNN structure used here is U-net, but other forms might perform better, which requires further research.

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