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Study on Applying Deep Learning to Reverberation Artifacts in Ultrasound Diagnosis

超音波診断における多重反射由来のアーチファクトへの深層学習適用に関する研究

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1. Introduction

Japan's aging population is expected to cause a strain on medical resources and to prevent patients from receiving enough treatment in major hospitals[1]. In such case, initial treatment is conducted in local clinics where high resolution diagnosis cannot be used for initial cost. Ultrasound (US) diagnosis is characterised by the low initial cost and simple usage. However, US diagnosis has lower spatial resolution than Magnitic Resonance Imaging (MRI) or X-ray CT. Especially, artifacts often appear in images and results in decreasing diagnostic qualities.

Reverberation artifacts, caused by multiple refrections of US waves between the organs and the US probe, sometimes depress image visibility. Duarte et al. [2] used Time of flight (TOF) for removing reverberation artifact from parallel three mediums. While this method is effective for parallel mediums, actual human organs have more complex shapes and the feasibility for actual human body needs to be considered.

In recent years, researches to improve US diagnosis using Deep Neural Network (DNN) has been conducted to detect breast cancers, to decrease specle noise, and to remove clutter noise. Mahdi et al. [3] conducted a research to remove artifact in echocardiographic images using Convolutional Neural Network (CNN), and showed better result than using Singluar Value Decompositon (SVD).

These DNN-based methods can be classified as either methods applying DNN to constructed images or ones applying to the measured raw signals, RF signals. The RF singals have more information than the constructed images have. Therefore, methods applying DNN to RF signals are expected to perfome better. Although methods applying to constructed images are considered effective for specific regions such as echocardiography, quite much datasets are needed when extended to whole human bodies. Watanabe et al. [4] applied DNN to RF Signal to remove bone artifacts and showed its effectiveness.

This study aimed at decreasing reverberation artifacts utilizing DNN to RF signal in US diagnosis with linear array probe. We evaluated artifacts caused by reberberation between the human bodies and the linear array, conducted simulation, and considered the effect of artifacts removal of DNN.

2. Method

In this study, we used DNN, a data-driven method, to remove artifacts. A pair of signals w/ and w/o reverberation needed to be generated from one medium. We trained DNN to convert signals w/ reverberation into signals w/o reverberation by the supervised learning. There are mainly two ways to generate datum: measuring RF signals using actual US probe, or calculating simulation. The former was not suitable for removal of reverberation using DNN because RF signals w/o reverberation could not be generated using actual probe. Therefore, we calculated US propagation simulation to obtain the datum.

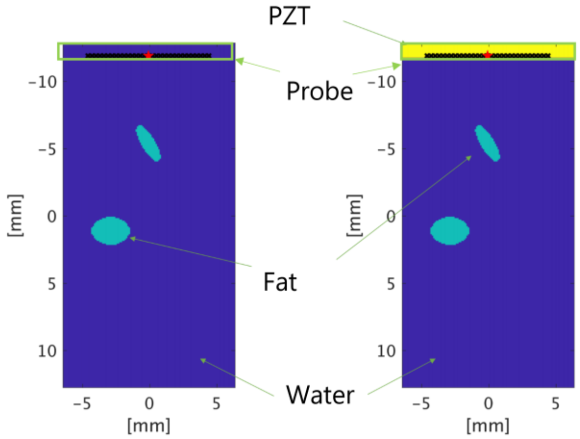


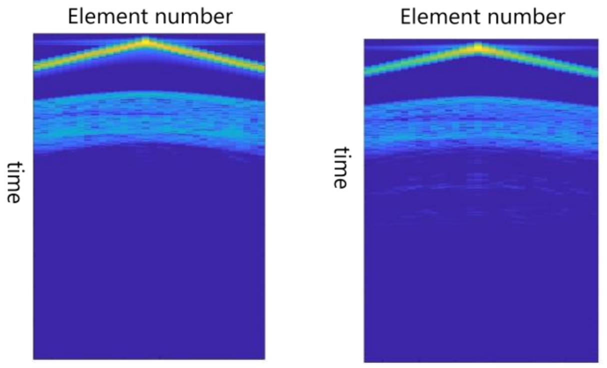
Fig. 1 Used medium in simulation (a)w/o reverberation, (b) w/ reverberation.

The simulation was performed utilizing MATLAB and its third-party toolbox, k-Wave. As shown in

Fig.1, we performed ultrasound propagation simulation in pairs of two mediums: one easily imitated real probe, and the other imitated virtual probe ,which had the same sound speed and density as water. The latter was not expected to cause reverberation. 100 pairs of RF signal was generated from simulation.

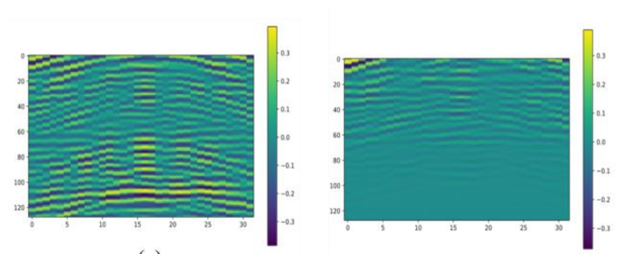
RF signals were processed to cut out in time domain based on the medium positions. DNN was trained to remove reverberation waves and applied to the preprocessed data. Resnet34+U-Net architecture was used as a backbone.

3. Result & Discussion



(a) (b)

Fig.2 Calculated RF signals. (a)w/o reverberation, (b) w/ reverberation.

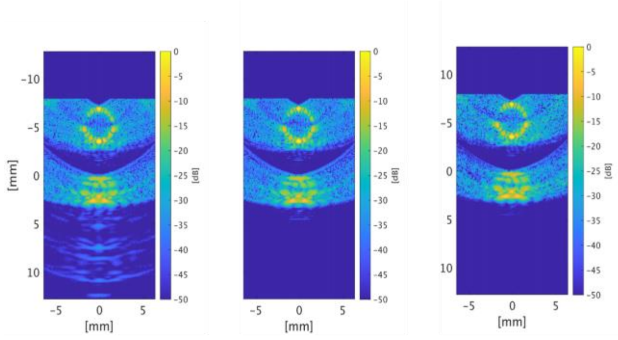


(a) (b)

Fig. 3 Modification of cropped RF signal including reverberation using DNN. (a)original RF signal, (b)processed RF signal.

Fig.2 showed calculated RF signals. RF signals w/ reverberation was collected by DNN, and the result of image construction was shown in **Fig.4.** Reverberation artifacts were decreased qualitatively. Signal to Noise Ratio(SNR) of modified image was 32.8 dB better than that of original image including reverberation. Targeted ellipse shape was not changed whereas streaky reverberation artifacts were deleted. DNN was considered to learn distinguishing and removing reverberation sucessfully.

However, another artifacts emerged in constructed ellipse region. This was one of limitations of this research. This artifact was considered not to derive



(a) (b) (c)

Fig.4 Change of constructed images. (a) w/ reververation, (b) w/o reverberation, (c) processed images by DNN.

from reverberation, but to derive from synthetic aperture, which was the algolithm used for image construction.

4. Conclusion

This research aimed at removing artifacts derived from reverberation between human bodies and ultrasound probes. RF signals w/ and w/o reverberation were generated through numerical simulations by changing simulation conditions. We tried to remove reverberation artifacts by using DNN. The images modified by the proposed method showed 32.8 dB larger SNR than original images, and the effect of artifact removal was shown qualitatively and quantitatively.

In this research, ultrasound probe was simplified and imitated, but real probes have more complex structures such as acoustic lens and matching layer, which reflect ultrasound wave in each boundary. The difference possibly become problem if the proposed method is applied to actual probe. For confirmation of principal and clinical application, futher studies is required such as simulation with more precise imitated probe, application to actual human body which has more complex structure, and removal of reverberation artifact coming from inside human bodies.

Acknowledgment

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