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Fast Cardiac Ultrasound with Deep Learning

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Abstract— **Fast ultrasound imaging is required for cardiac ultrasound imaging. Divergent wave imaging (DWI) can be used to increase imaging frame rate but produces lower quality images. In this work, a Convolutional Neural Network (CNN) is used to improve DWI images to have a similar quality to the conventional single-line acquisition (SLA) images. The CNN was demonstrated to improve DWI images by a mean MS-SSIM of 0.26 for 500 testing images.**

Clinical Relevance— **Faster and higher quality cardiac ultrasound images can provide more information enabling more accurate assessments of cardiac structure and function.**

I. Introduction

Cardiac ultrasound imaging is widely used for evaluating cardiac structure and function [1]. It is a non-invasive and easy-to-use imaging modality that can provide high-resolution imaging with real-time feedback. Imaging speed or frame rate is an important factor for imaging fast physiological processes such as the motion of the heart to minimize blurring and motion-related artifacts. In conventional SLA ultrasound imaging, the frame rate is determined by the required number of focused beams transmitted into the medium. In DWI, the frame rate is increased by using unfocused beams to image a larger area per transmission and reducing the number of transmissions needed. However, this results in the deterioration of image quality (e.g., resolution, contrast, and noise). Deep learning has been demonstrated to achieve state-of-the-art performance in many biomedical imaging problems including image reconstruction [2]. In this work, CNNs are used to improve the image quality in DWI cardiac ultrasound images while preserving rapid acquisition times.

II. Methods

Cardiac ultrasound images from the Stanford EchoNet database were used as anatomical templates to generate *in silico* training and testing data. The MATLAB ultrasound simulation toolbox (MUST) was used to simulate image acquisition using the standard SLA and DWI with a 64-element planar sensor [3]. SLA had 30 transmit events, and DWI had 6 transmit events. Noise was added to the simulated ultrasound signal resulting in a peak-signal-to-noise ratio (PSNR) of 30 dB for SLA and 15 dB for DWI. B-mode images were initially reconstructed for each imaging method using the delay-and-sum beamforming method. A training dataset comprised of 1000 images, and a testing dataset of 500 images were created.

The task of improving DWI image quality was formulated as a supervised learning problem, where the CNN takes the DWI image as an input and attempts to reconstruct a higher quality SLA-like image. The fully dense UNet (FD-UNet), a variant of the widely used UNet CNN for biomedical imaging, was used for image reconstruction [2]. The CNN was implemented in Tensorflow v2.3 and trained for 100 epochs. The multiscale structural similarity index (MS-SSIM) was used to measure the image quality of CNN reconstructed images assuming the SLA images as the ground truth. MS-SSIM ranges from 0 to 1 and measures the similarity between two images in terms of structure, contrast, and luminance.

III. Results

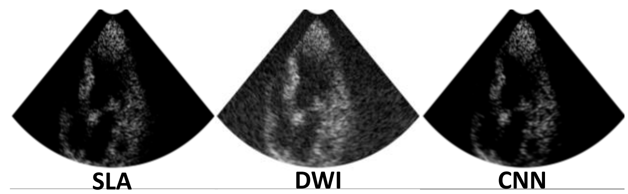

Figure 1. Image simulated with (left) SLA with delay-and-sum (middle) DWI with delay-and-sum, MS-SSIM: 0.72 (right) DWI enhanced by CNN, MS-SSIM: 0.93.

The CNN was successful in improving the image quality of the DWI image (Fig. 1). There was less noise in the CNN reconstructed image, and the cardiac structures such as the heart chamber walls and valve were better defined. The improvement in image quality was consistently observed for the N=500 testing images. The CNN improved the DWI image by a mean MS-SSIM of 0.26 ± 0.05 compared to the initial DWI B-mode image.

IV. Discussion & Conclusion

Using deep learning with DWI, cardiac ultrasound imaging can be performed 5x faster with a minimal loss in image quality compared to the SLA approach. This enables for improved imaging of cardiac motion and reduces potential artifacts and blurring due to slow image acquisition. Having improved imaging is essential for increasing the accuracy in identifying and diagnosing cardiac pathologies.

References

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