An Adversarial-learning Framework to Recover IQ Signals from Random Sparse-aperture Transmissions in Synthetic Aperture Ultrasound

Background, Motivation and Objective

Synthetic aperture ultrasound imaging produces high quality images through two-way dynamic focusing. Using a limited number of sub-aperture transmissions enables high frame rate imaging of fast tissue dynamics but degrades image quality. A prior Multi-level Sensing Adversarial Framework (MSAF) recovered in-phase and quadrature (IQ) signals pertaining to missing sub-apertures from a uniformly sampled subset, yielding full-aperture equivalent imaging. Building on this success, this study aims to generalize MSAF to other sampling schemes and investigate the impact of the sampling scheme (e.g., random sparse-aperture transmission) on IQ signal recovery.

Methods

To make MSAF handle any combinations of sparse-aperture transmissions, a new generator is built to learn mapping of IQ signals between randomly sampled and missing sub-apertures given deep prompts of aperture indices. As shown in Fig. (a), input sub-aperture indices are embedded as attention maps on three scales, which are then applied to feature maps in three layers of the encoder, respectively. Output sub-aperture indices are applied to the decoder in the same way. Those prompts guide the generator concerning which sub-apertures are selected or missed. For adversarial learning, frame-wise global and aperture-wise attribute discriminations constrain the recovered signals from the perspectives of cross-subapertures within a full frame and local attributes within a sub-aperture, respectively. Our dataset includes 18,450 sub-aperture beamformed IQ frames of *in vivo* human hearts, acquired at 1600 fps using a Verasonics Vantage 256 system with a P4-2 phased array and diverging wave transmissions.

Results and Discussion

The new MSAF model with random sub-aperture transmissions achieved 29.30 PSNR, 0.67 SSIM, 0.08 MSE in the IQ domain, and 31.88 PSNR, 0.79 SSIM, 0.04 MSE in the B-mode image domain (Fig. (b)). Compared to uniform sampling, random sampling produced lower PSNR by 7.11%, lower SSIM by 11.67%, and higher MSE by 10% (Fig. (c)). The findings suggested that uniform sampling would be the scheme of choice for raw signal recovery.