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Sub-wavelength Imaging Methodology for Medical Ultrasound Applications

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Abstract

Due to its inexpensive and non-invasive nature, ultrasound imaging has become the preferred medical imaging modality. Despite its high demand, its use is limited due to the fact that ultrasound images suffer from noise and image artifacts such as sidelobes and reverberation artifacts. Over the past decades, a vast amount of research has been carried out to improve the resolution and contrast of images through various techniques that are based on adjusting the shape of the ultrasonic excitation, or improving the so-called beamforming function at the receiver side, or utilizing image post-processing.

In this thesis, there are three novel ultrasound imaging methods discussed. The first technique, named Compressive Ultrasound or CU is based on applying randomized transform to the RF data and thereafter compressing the data, thus reducing the hardware requirements. The random modulation at the receiver side ensures that the frequency content is spread across the entire spectrum, thus conserving information. The results from this method are compared to traditional ultrasound B-mode images. The proposed method exhibits imaging contrast and resolution similar to traditional ultrasound but with much reduced computational complexity compared to compressive sensing techniques.

Next, a coherent imaging methodology referred to as Ultrasound Coherent Imaging (UCI) is presented. This method is based on model characterization of the medium being imaged and convex optimization methods for image reconstruction. The UCI method deploys front-end architectures and post-processing steps of image reconstruction that are dramatic departure from conventional approaches and has the potential to disrupt the state-of-the-art in ultrasound imaging. Experiments using the Verasonics ultrasound scanner and simulations using Field II MATLAB package were performed for various phantoms. The results showed images of high contrast ratio and super-resolution capabilities when compared to images from traditional B-mode ultrasound. It has been experimentally verified that the UCI technique is able to achieve a spatial resolution 13 times better than the traditional US (depth of 9 cm).

Lastly, an optimal ultrasound system with the resolution capabilities of the Ultrasound Coherent Imaging method and optimized hardware architecture from the proposed Compressive Ultrasound is presented. The reduced computational and hardware complexity has made this design a good candidate for future portable ultrasound systems with super-resolution capabilities.