압축센싱을 기반 초해상도 초음파 이미징

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Unfocused Super-resolution Ultrasound Imaging using Compressive Sensing

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Abstract

In this work, we propose a new unfocused image reconstruction approach based on Compressive Sensing. We compare our results with conventional focused techniques. Unlike focused B-mode imaging resolution of proposed method does not depend on diffraction limit. We provide results and validation of proposed method in simulation software. Our simulation shows significant improvements in spatial resolution.

I. 서론

In conventional sonography best resolvable resolution considered to be equal to two wavelengths. For ultrasound systems that operate at frequencies ranging from 3~15 MHz the finest resolvable resolution would be equal to 1~0.2 mm respectively. The diffraction limit determines resolution of conventional sonography systems. However, we show that it is possible to use interference of ultrasound waves to improve spatial resolution in medical ultrasound. Our work motivated by the fact that ultrasound fields can be accurately described using Huygens-Fresnel principle. Then, received by the array of elements RF signals can be considered as a superposition of reflected back, from inhomogeneity in the medium, ultrasound fields.

The objective of this work is to improve the spatial resolution of ultrasound systems. We propose a new ultrasound imaging method that provides much greater details of small structures that usually cannot be observed in conventional sonography. In our work we use modified synthetic transmit aperture algorithm and Compressive Sensing theory Fig. 1. During transmission all transducer elements are assigned with code waveforms, then a modified synthetic transmit aperture algorithm is used to acquire RF data for all transmit/receive pairs in ultrasound array. Prior to reconstruction we calculate a spatial impulse response of single point scatterer placed on a virtual grid Fig. 2. Obtained spatial impulse responses are used to construct Compressive Sensing matrix as shown on Fig. 1.

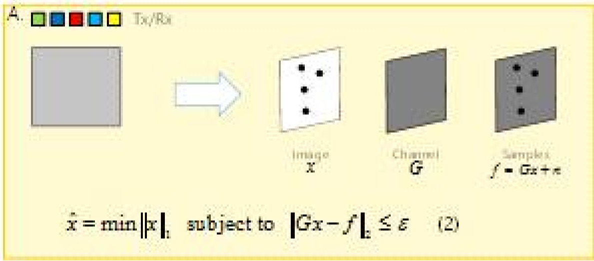

그림 1. System model of unfocused ultrasound imaging using Compressive Sensing

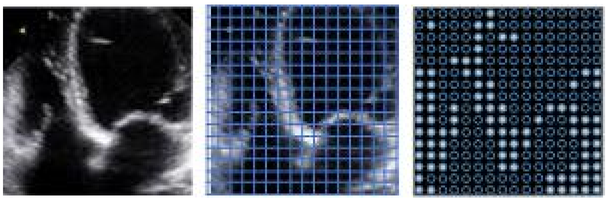

그림 2. Ultrasound object on virtual grid

II. 본론

In this section, we introduce a general description of proposed ultrasound imaging system. Ultrasound image reconstruction can be modeled as a system of linear equations as

$$y = Gx, \qquad (1)$$

where x is a 2D ultrasound image, such as human body or ultrasound phantom, which can be viewed as a N×1 vector, denoted by G the M×N sensing matrix.

In our simulation, we consider two methods to construct sensing matrix: Individual Spatial Impulse Responses (ISIR) and Combination of Spatial Impulse Responses (CSIR)

2.1 Individual Spatial Impulse Responses (ISIR)

In first method a compressive sensing matrix constructed from individual spatial impulse responses. Columns of matrix G are the derived impulse responses for point scatterer on the virtual grid Fig. 3.. Where each column corresponds to one spatial impulse response. Given measurements y and matrix G, the CS algorithm must recover image x. Signal responses of two closely placed points will be highly correlated. However ultrasound images considered on grid with 0.5 mm spacing can be reconstructed without any errors.

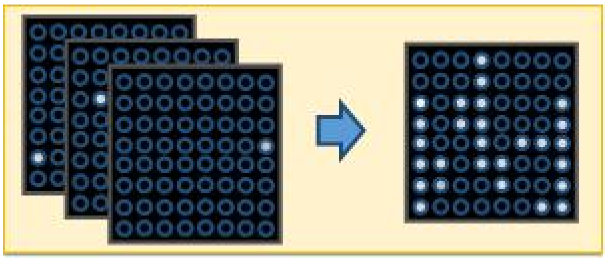

그림 3. Sensing matrix constructed by Individual Spatial Impulse Responses (ISIR)

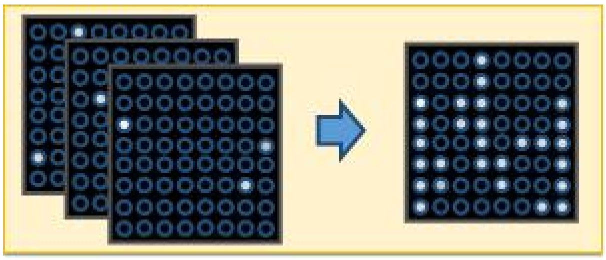

그림 4. Sensing Matrix constructed by Combination of Spatial Impulse Responses (CSIR)

2.2 Combination of Spatial Impulse Responses (CSIR)

In order to reduce coherence of sensing matrix in previous method we propose to use a linear combination of 3 spatial impulse responses as shown in Fig 4. This can be done by multiplying derived in 2.1 sensing matrix G with zero-one matrix D, where columns of D have only 3 randomly placed one's. By introducing matrix D we were able to reduce coherence of sensing matrix, eventually this will lead to some errors during reconstruction because not every ultrasound image can be described by new matrix GD. However, with careful design of matrix D, or in special cases where object has sparse structure, slightly bigger reconstruction error does not change overall quality of recovered ultrasound images. Then problem defined in (1) will have a form as

$$y = GDs = Bs, \qquad (2)$$

IV. 결론

In our simulation results we consider that ultrasound images can be defined on virtual grid. Sensing matrix were constructed using measured spatial impulse responses. In Fig. 5. we compare focused

B-mode images with proposed modified STA method based on Compressive Sensing. From images, it is clearly seen that sidelobes in B-mode images corrupt all image. While in the Compressive Sensing based methor reconstruction of point scatterers is exact.

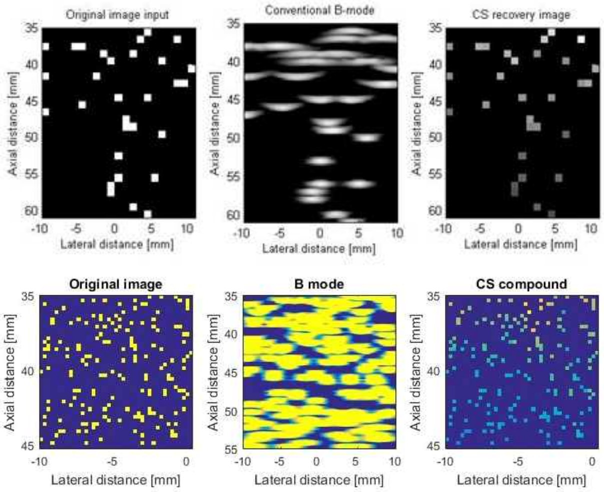

그림 5. Reconstructed CS images compared with B-mode images.

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