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UltrasoundToGo RTD 2013

FNSNF

Compressed sensing based ultrasound image reconstruction

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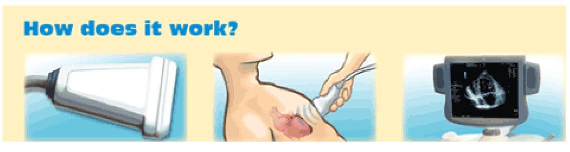
Introduction & Motivation

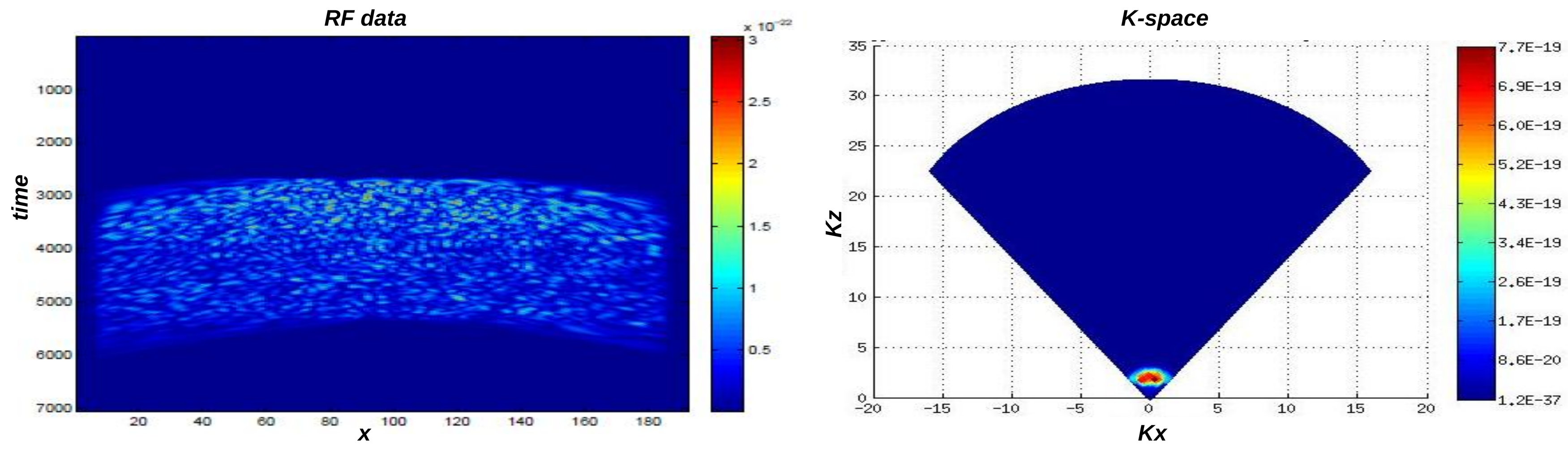
- Today, ultrasound (US) imaging is one of the most widely used imaging technologies in medicine.
- The basis of its operation is the transmission of high frequency sound into the body followed by the reception, processing, and parametric display of echoes returning from structures and tissues within the body (Pulse-echo).



- The most frequently used technique to reconstruct an image is the beamforming approach. This process consists of steering and focusing the acoustic pulses using appropriate delays to image one specific object
  - Several emissions frames
  - High power & data rate
- Our approach explores new sensing and reconstruction methods based on the theory of **Compressed Sensing**.
  - Reduce the data rate
  - Reduce acquisition power consumption

Frequency domain approach (k-space)

- We send just one plane wave and then at reception we synthesize the response of different steering angles.



- It is equivalent of projecting the delay &sum RF data to a k-space.
- Each measurement reads as $y_i = \int\int r(x,z)e^{-i2\pi(u_i x+v_i z)}dxdz$
- In the discrete setting, we write

  y=φr

  where φ the non-uniform FFT operator
- Hence, recovering **r** is an ill-posed problem because the number of measurement is lower than the number of pixel of the image, i.e. dim(r) > dim(y) .

Solving the ill-posed inverse problem

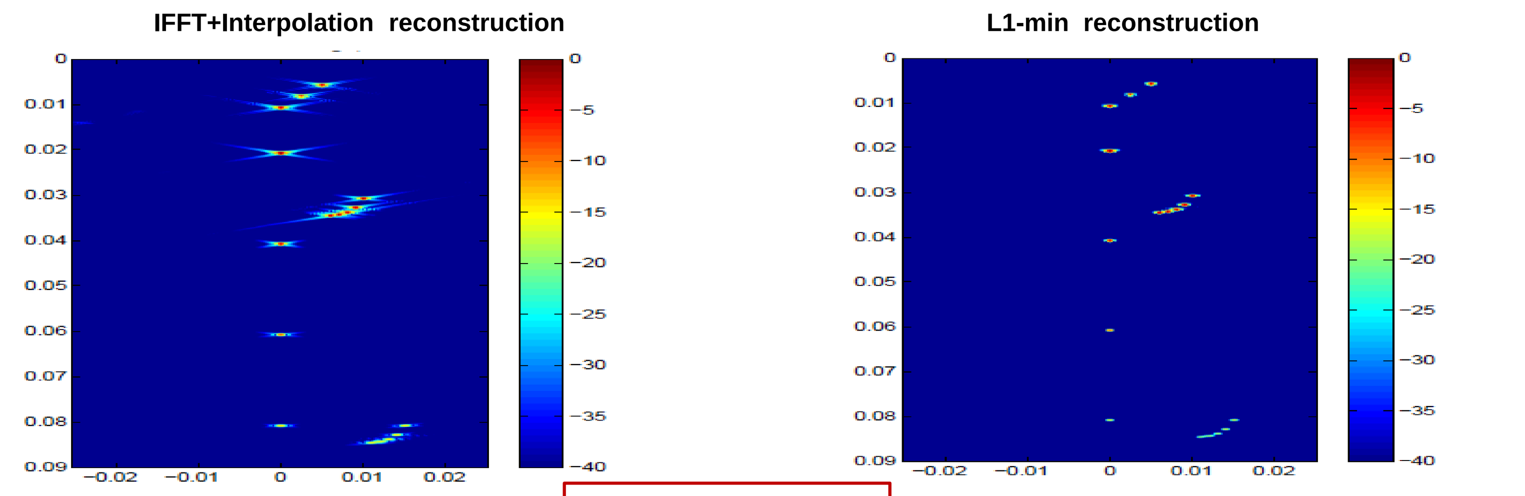
- We exploit the property that the images are sparse in a representative dictionary Ψ. Using the l1 norm as the sparsity measure, we can reconstruct our signal using :

$$\hat{r} = \arg\min_{\bar{r}\in\mathbb{C}^N} \|\Psi^H \bar{r}\|_1 \text{ subject to } \|y - \Phi\bar{r}\|_2 \le \epsilon$$

- In order yield the correct solution, some properties must be ensured
  - Incoherence between sensing basis φ and representative basis Ψ
  - The signal must be sparse enough in Ψ

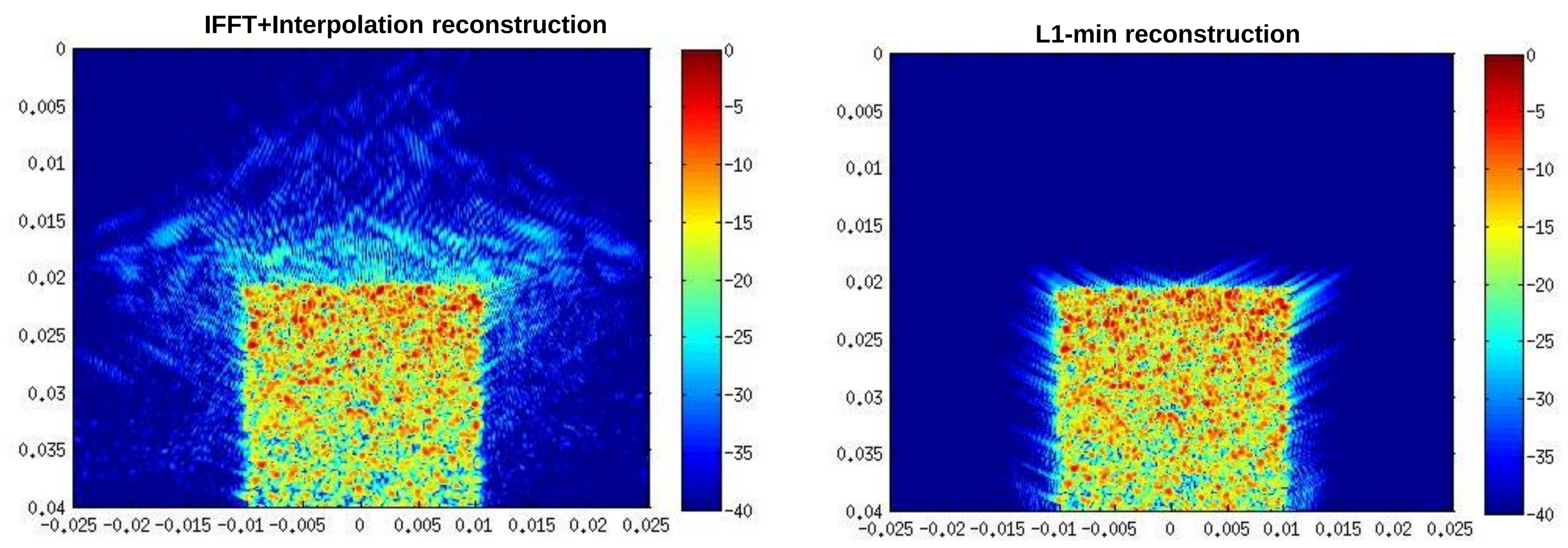
1st hand results

- Generated phantom made with a small number of distributed scatterers.



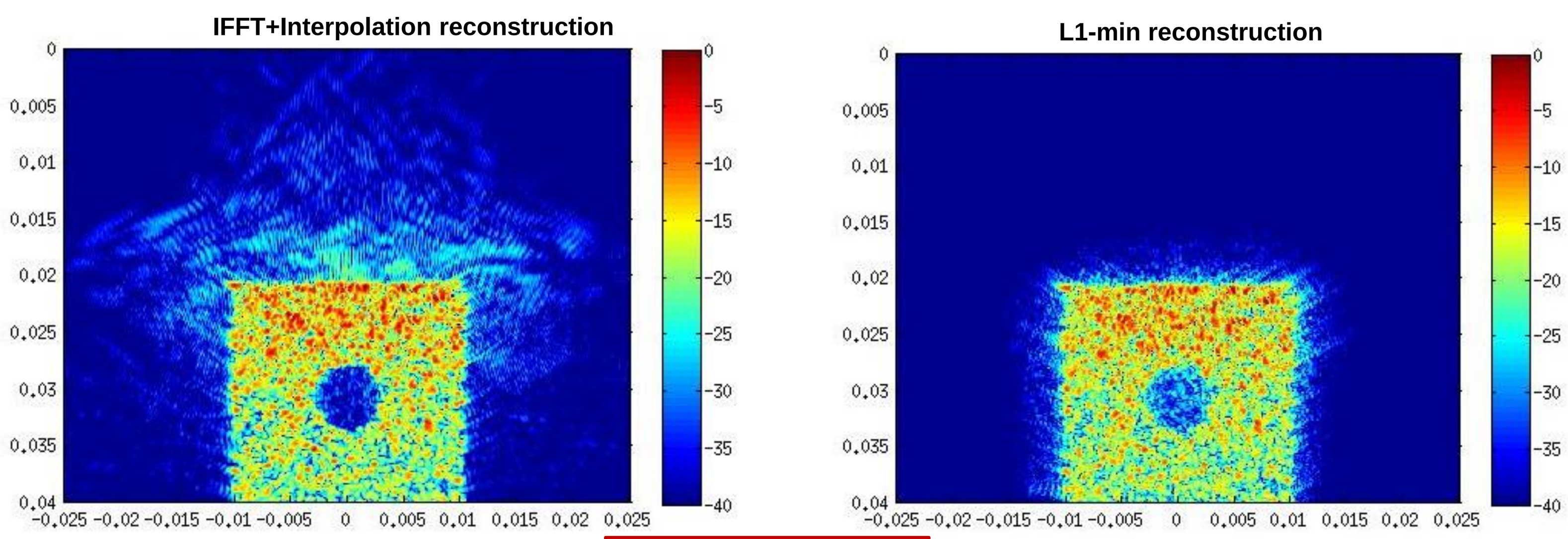
Ψ: Dirac basis

- Speckle Reconstruction without occlusion.



Ψ: Wave atoms

- Phantom with occlusion.



Ψ: Wave atoms

Discussion « to go »

- Yield a **High Resolution** benefit : resolution does not depend on the number of array elements nor on the time sampling rate (as opposed to classical methods).
- Acquisition can be done much faster because we need less samples. This is crucial for **power & data reduction**.

Conclusions & Future Directions

- Fourier based approach for the measurement model is presented.
- Reconstruction based on NUFFT and Compressive Sensing.
- CS reconstruction achieves better resolution than pure Fourier reconstruction
- Undersampling need to be fully evaluated.
- Other acquisition methods should be deeply investigated.