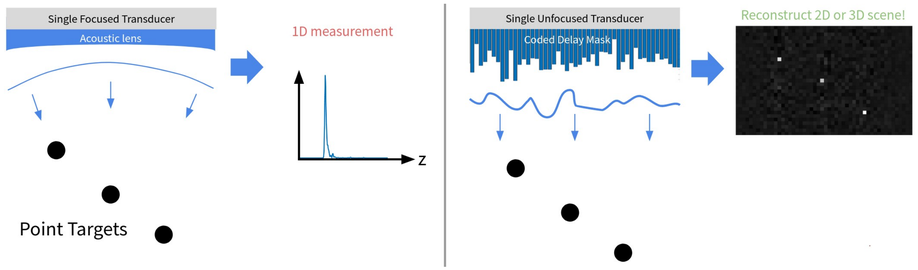
Single Element Ultrasound Imaging with Compressed Sensing

William Meng
wlmeng@stanford.edu

EE 367 Final Project, Winter 2021

Motivation

- Conventionally, a single ultrasound transducer can only capture 1D depth data, unless it is mechanically scanned.
- A *coded aperture* can encode lateral information into a single temporal signal to perform 2D or 3D imaging [1, 2, 3].



Related Work

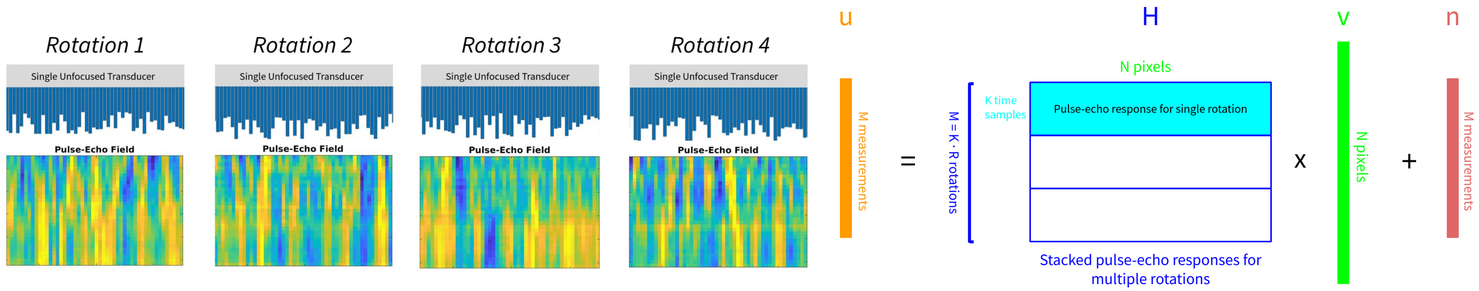
- 2D/3D ultrasound imaging is typically done with *ultrasound arrays* consisting of many elements, but this requires greater hardware complexity and cost.
- Other coded aperture techniques for ultrasound imaging use a 3D printed delay mask [1], Hadamard-encoded amplitude mask [2], or a scattering layer [3].

References

[1] P. Kruizinga, et al, “Compressive 3D ultrasound imaging using a single sensor”, Science Advances, Vol. 3, No. 12, December 2017.
[2] E. Hahamovich, A. Rosenthal, “Ultrasound Detection Arrays Via Coded Hadamard Apertures”, IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, Vol. 67, Issue 10, Oct. 2020.
[3] X. Luís Deán-Ben, et al, “Acoustic Scattering Mediated Single Detector Optoacoustic Tomography”, Physical Review Letters, Vol. 123, Iss. 17, 25 October 2019.

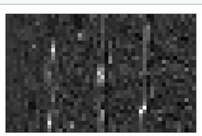
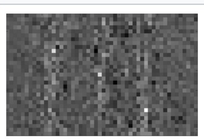
Methodology

- Approximate physical mask as a *delay profile.*
- Linear image formation model based on temporal *pulse-echo response* at each pixel.
- Multiple mask *rotations* provide additional diverse measurements of spatial information.
- Reconstruct image with Least Norm (PCG or Pseudoinverse) or ADMM.



Simulated Results

- Generated synthetic data with 90 dB electronic SNR based on 3 point targets.
- Reconstructed with Least Norm (PCG) and ADMM for: (a) No mask (b) R=1 (c) R=4
- Characterized degradation of Least Norm (PCG) image reconstruction vs electronic SNR for R=4.
- See paper and presentation for additional results.

Ground Truth	(a) Reconstructed (No Mask)	(b) Reconstructed (Mask with 1 rotation)	(c) Reconstructed (Mask with 4 rotations)
			
PSNR:	12.67 dB	8.78 dB	19.99 dB
Artifacts:	Double targets	Background noise	Minimal

Elec. SNR = 60 dB	Elec. SNR = 30 dB	Elec. SNR = 20dB
		
19.93 dB	17.39 dB	14.16 dB

Reconstructed image noise increases with electronic noise.