

Learning Beamforming in Ultrasound Imaging

Ortal Senouf

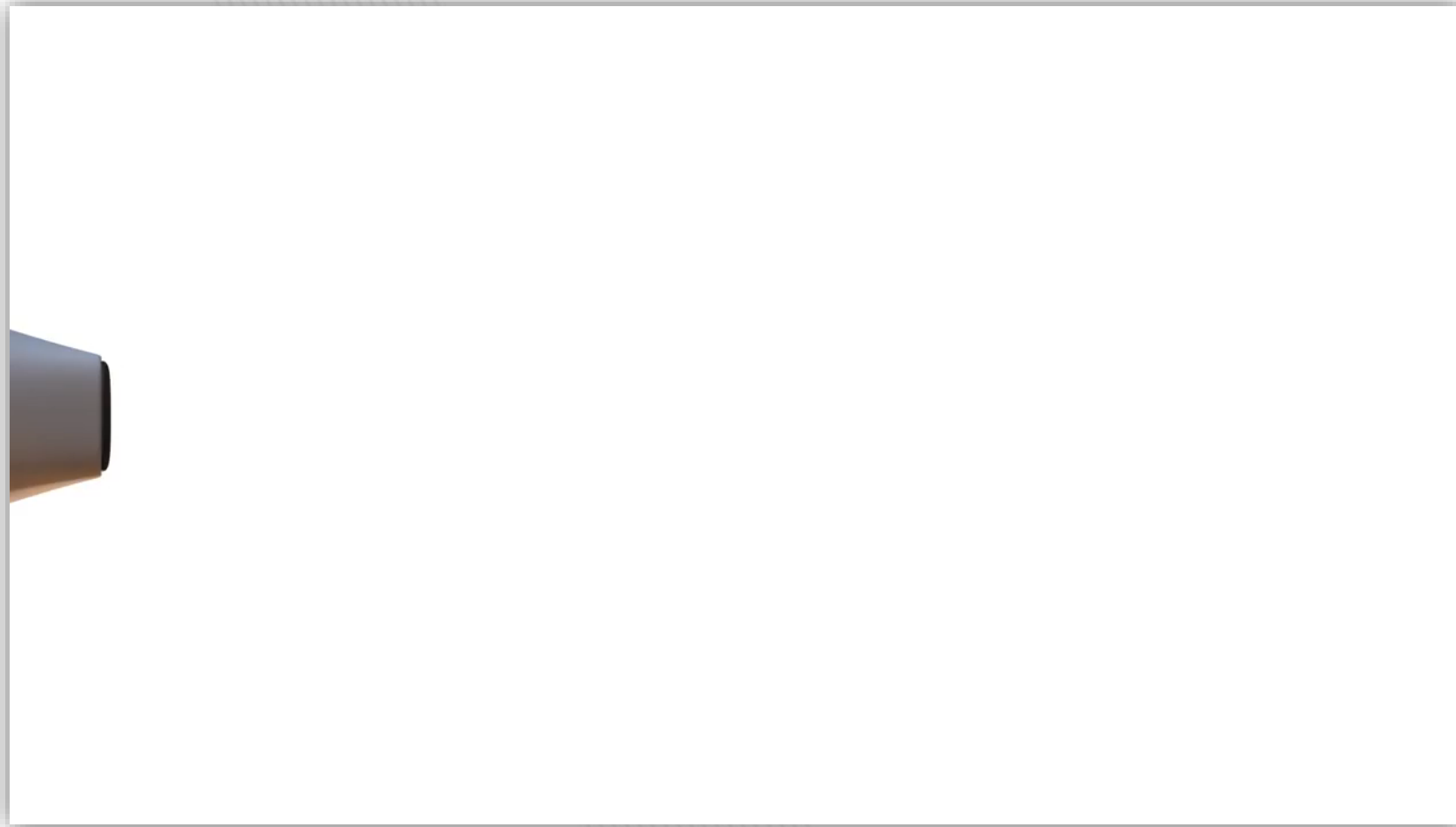
Supervised by: Prof. Alex Bronstein, Prof. Michael Zibulevsky

March 18, 2019

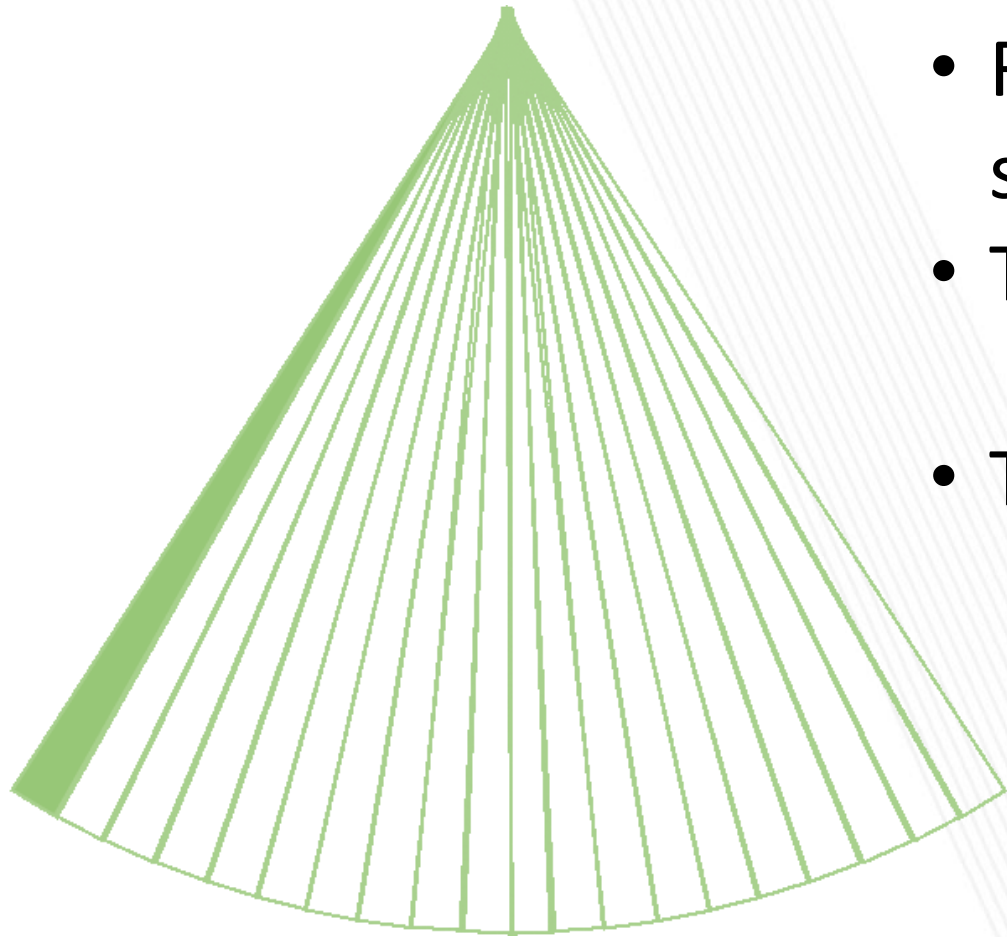
How does Ultrasound work?



Beamforming



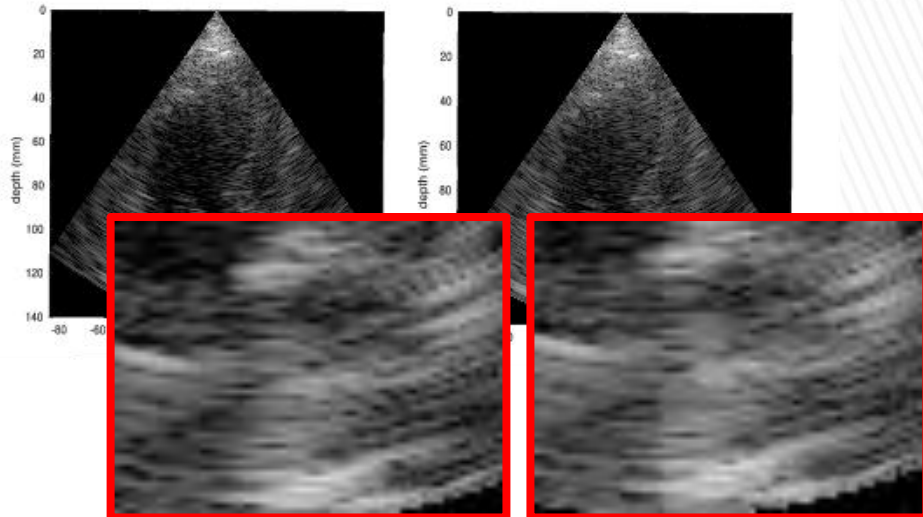
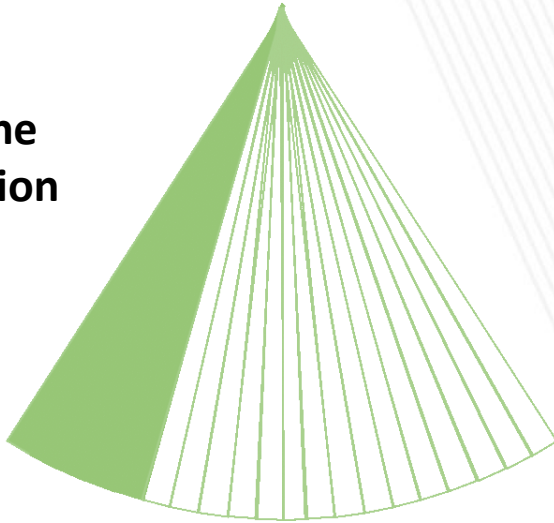
Transmit(Tx)/Receive(Rx) switch



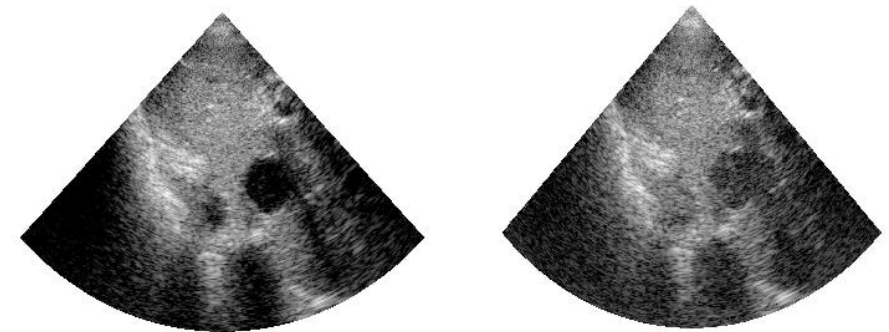
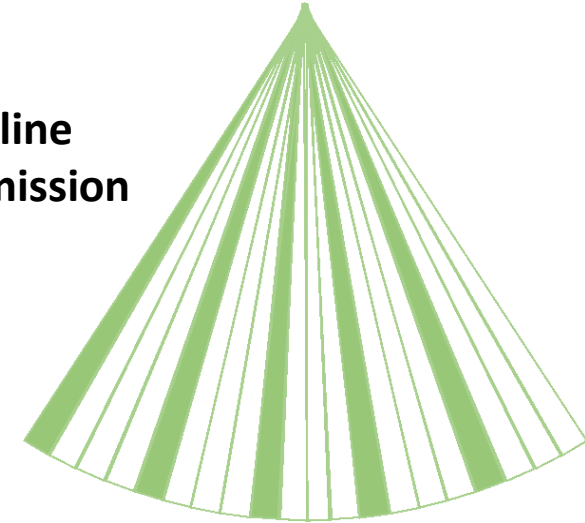
- Frame-Rate is bounded by speed of sound
- Tx events \uparrow Frame-Rate \downarrow image quality \uparrow
- Tx events \downarrow Frame-Rate \uparrow image quality \downarrow

Fast Ultrasound methods

MLA-
Multi-line
acquisition

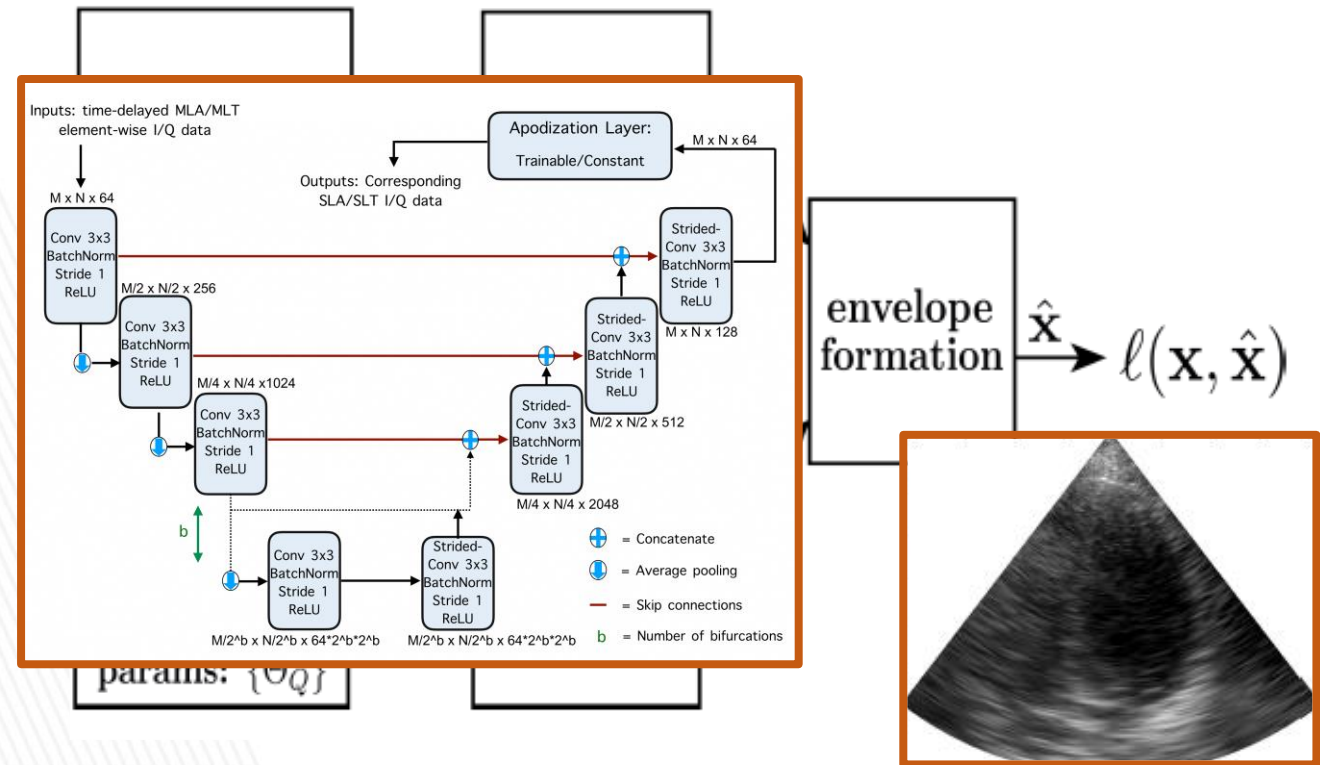


MLA-
Multi-line
transmission



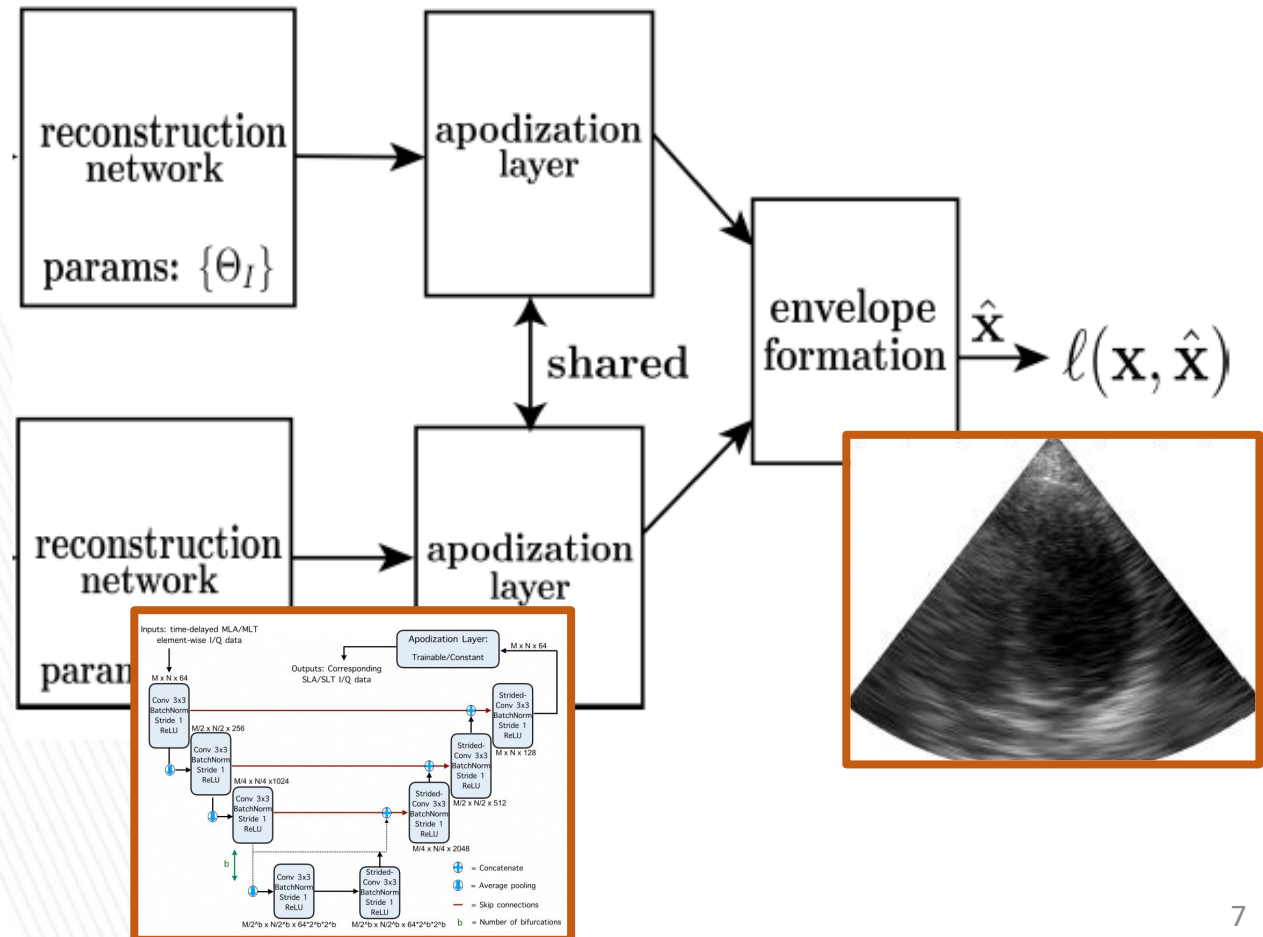
Previous work – Rx

- Solving the inverse problem, from measurements to full signal



Previous work – Rx

- Solving the inverse problem, from measurements to full signal

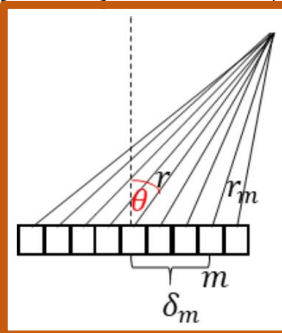
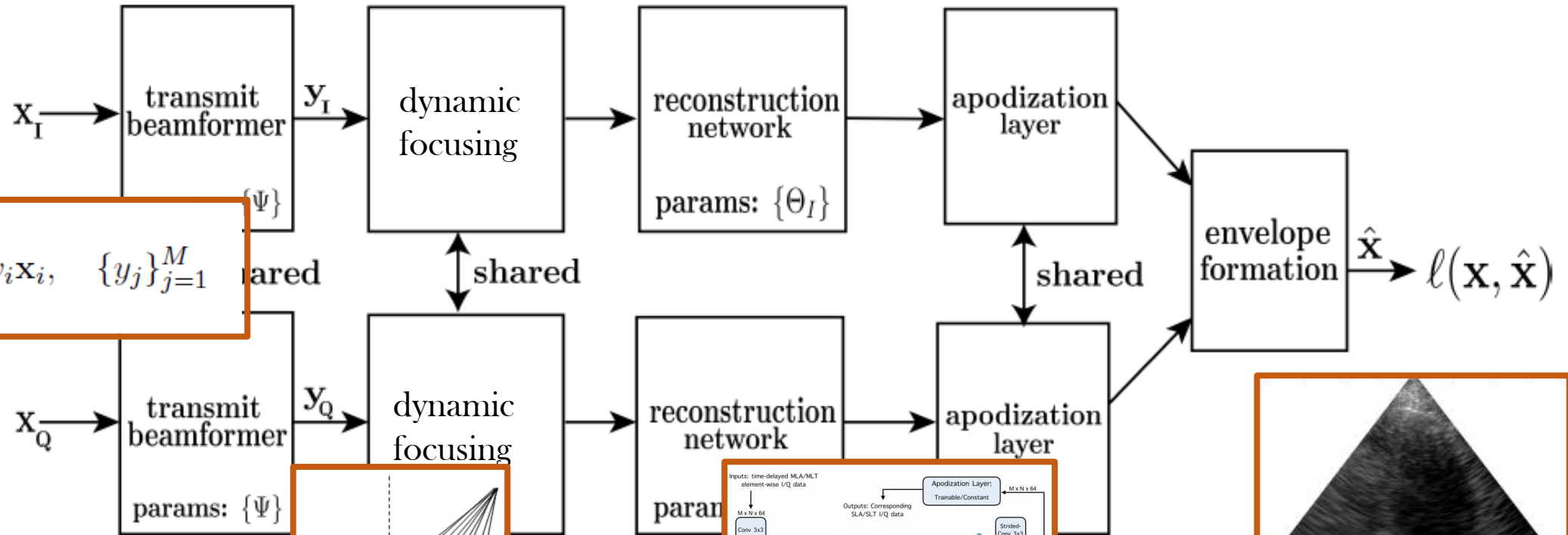


Current work – Tx+Rx

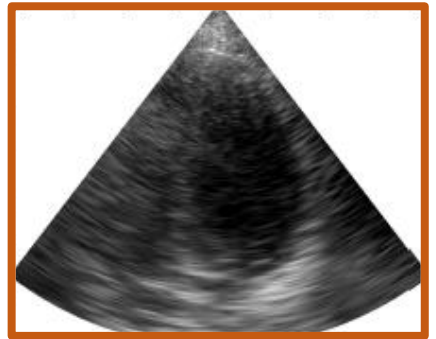
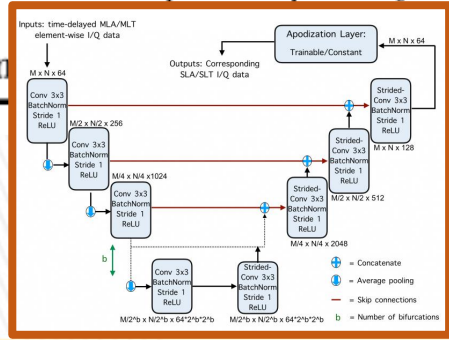
- Learning to measure and reconstruct, end-to-end

Emulation

$$y_j = \sum_{i=1}^L \psi_i x_i, \quad \{y_j\}_{j=1}^M \text{ shared}$$

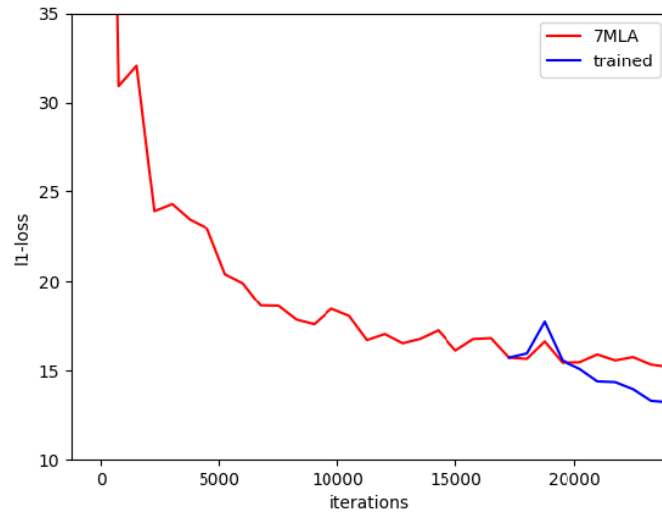


$$\Delta t_m = \frac{r - \sqrt{r^2 + \delta_m^2} - 2r\delta_m \sin \theta}{c}$$

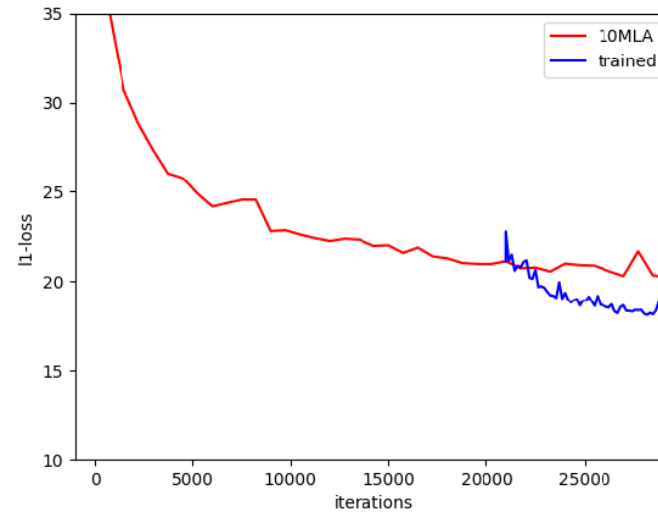


Learning Beamforming- Training

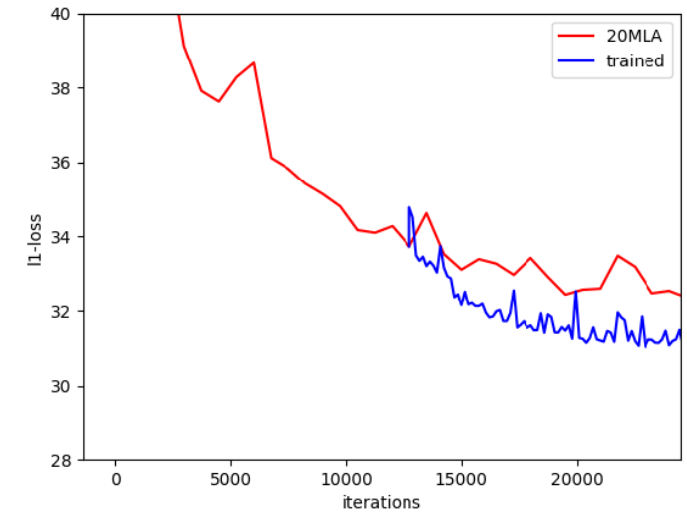
7MLA: validation error



10MLA: validation error

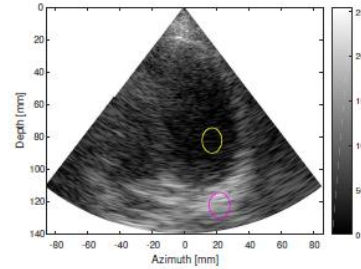


20MLA: validation error

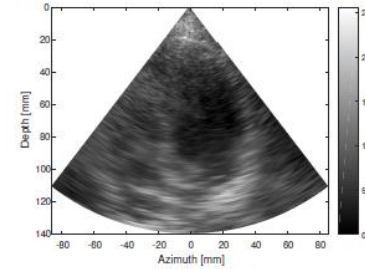


Learning Beamforming- Results

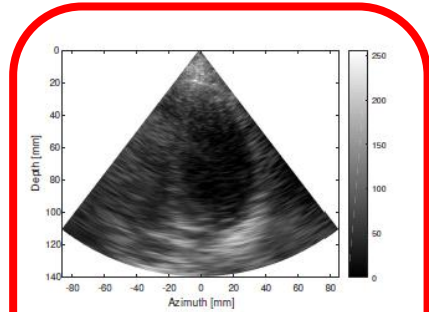
- Learnable beam pattern design:



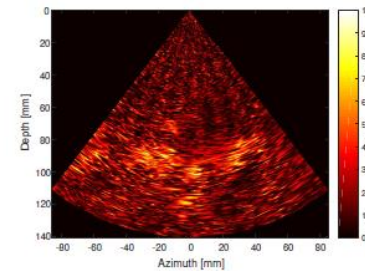
(a) SLA



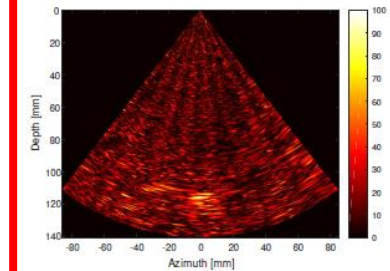
(b) Learned Rx 20-MLA



(c) Learned Tx-Rx 20-MLA

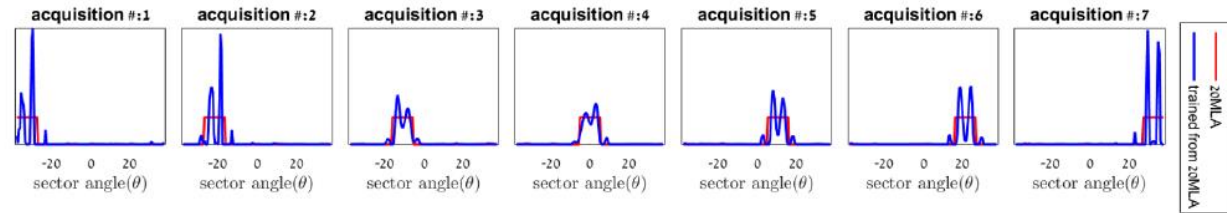


difference((b), (a))



difference((c), (a))

	7-MLA			10-MLA			20-MLA		
	PSNR	SSIM	L1-error	PSNR	SSIM	L1-error	PSNR	SSIM	L1-error
Fixed Tx – DAS	33.76	0.955	–	32.34	0.941	–	29.6	0.91	–
Learned Tx – DAS	34.03	0.96	–	32.73	0.95	–	29.87	0.916	–
Learned Rx	42.56	0.987	19.14	39.56	0.975	24.31	35.02	0.924	38.36
Learned Tx-Rx	43.4	0.99	15.94	39.98	0.98	22.19	35.32	0.95	36.24



Vedula, Sanketh, et al. "Learning beamforming in ultrasound imaging." *arXiv preprint arXiv:1812.08043* (2018).
 Accepted to MIDL 2019

Take-home message

- Proof-of-concept – jointly learned Tx/Rx performs better than handcrafted alternatives
- Joint learning of forward & inverse models -very interesting optimization problem
- Black-box emulation/simulation
- Should be implemented on real machine

Joint work with:



Sanketh Vedula
CS, Technion



Grigoriy Zurakhov
BME, Technion



Alex Bronstein
CS, Technion



Michael Zibulevsky
CS, Technion



Oleg Michailovich
U of Waterloo



Dan Adam
BME, Technion



Diana Gaitini
Medicine, Technion
RAMBAM hospital

Thanks!