Distributed Aberration Correction in Liver Imaging via Iterative Model-Based Sound Speed Estimation

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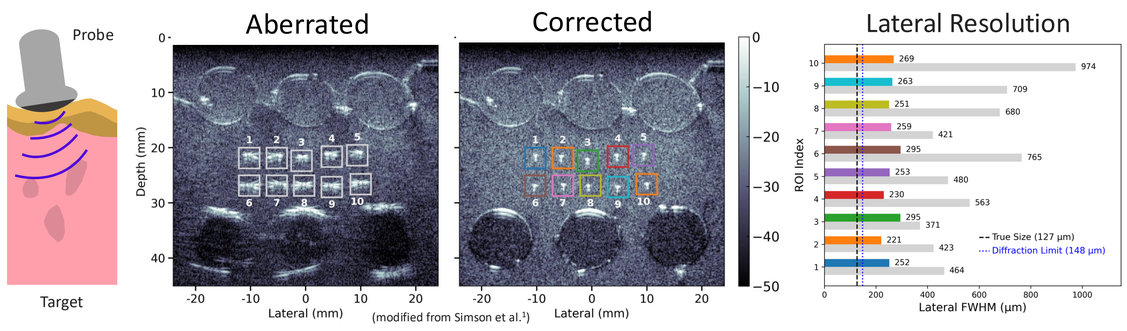
Motivation

- Overweight and obesity affect nearly 73% of U.S. adults (43% worldwide), and this global epidemic degrades medical ultrasound image quality because of increased body habitus, complicating accurate diagnosis (Fryar et al., 2018; WHO, 2022).
- Clinical ultrasound scanners assume a constant tissue sound speed. However, human tissue is highly nonuniform, causing ultrasonic wavefront distortion which leads to B-mode defocusing, reduced lateral resolution, and a decrease in contrast.



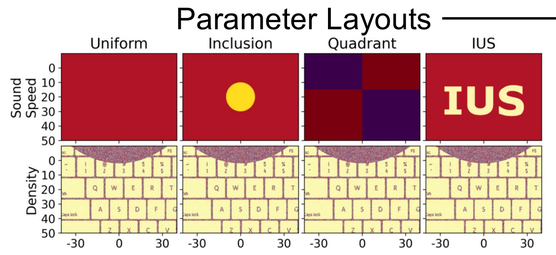
- An unmet clinical need exists for improving image quality via aberration correction.

Methods

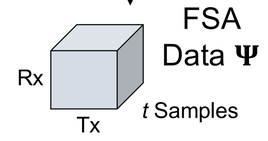
- Adapted a differentiable beamforming model for aberration correction via sound speed estimation[1] to work with experimental curvilinear transducer data.
- MimickNet[2] was applied to improve in vivo data for B-mode post-processing.

Simulation

k-Wave and QUPS[3]
Curvilinear Array
- Convex array
- 128 elements
- 3.7 MHz f_c
- FSA sequence

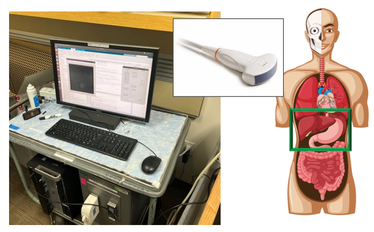


k-Wave + QUPS



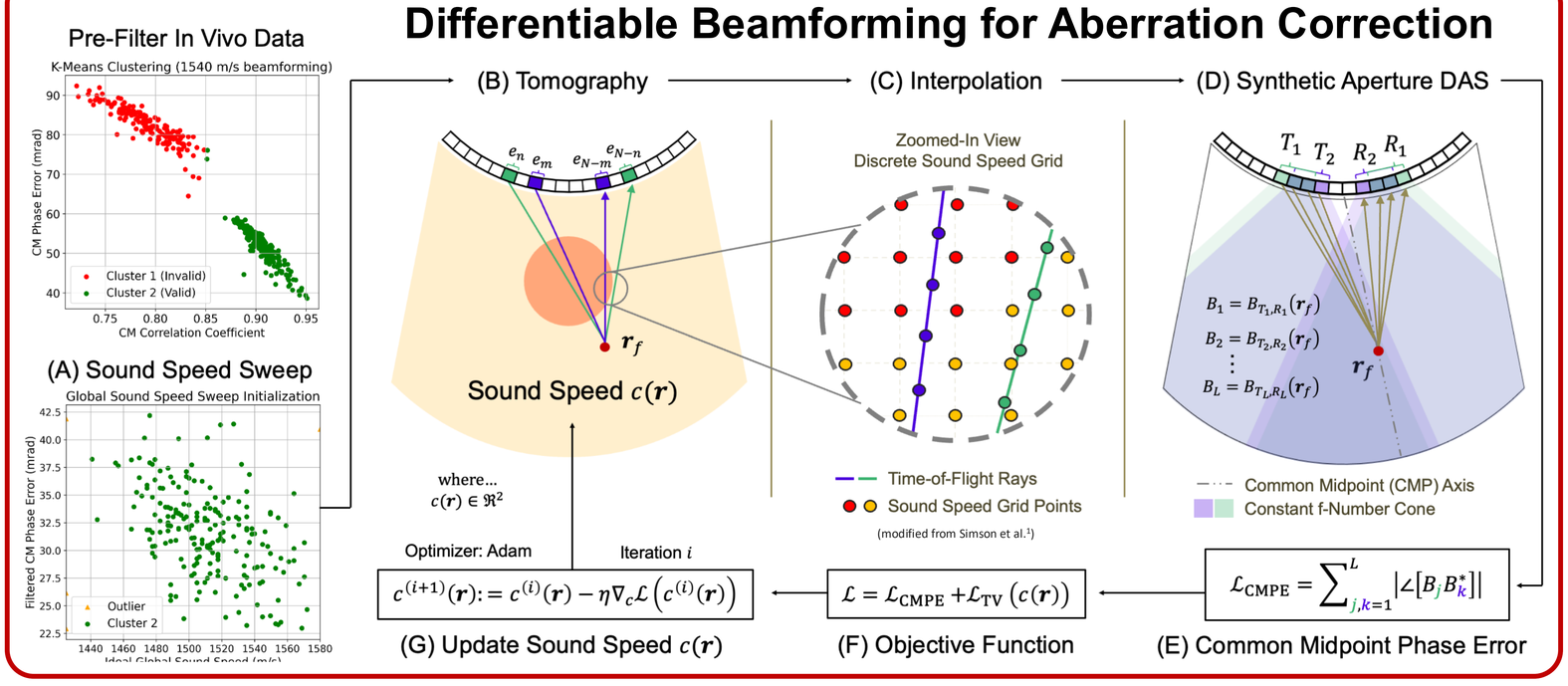
In Vivo Liver

Verasonics Vantage 256
Verasonics C5-2v
- Convex array
- 128 elements
- 3.9 MHz f_c
- FSA sequence



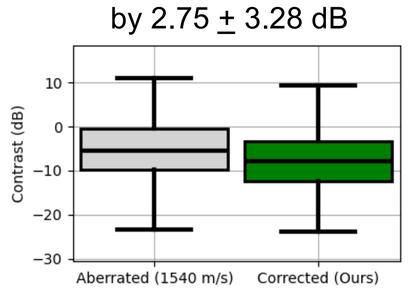
- Human liver imaging
- Male and female subjects
- 59 high-BMI subjects
- 375 total acquisitions
- Protocol IRB-56630 (informed consent given)

Differentiable Beamforming for Aberration Correction

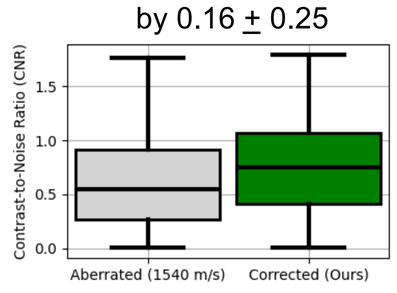


Quantitative Results

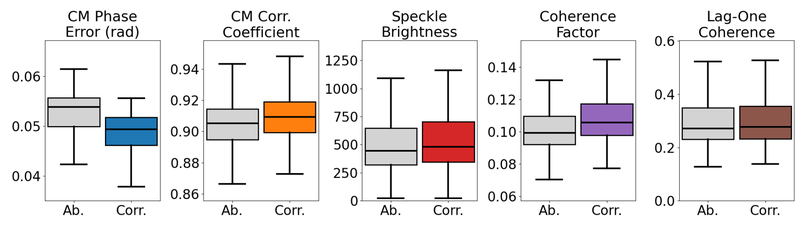
Contrast improved by 2.75 ± 3.28 dB



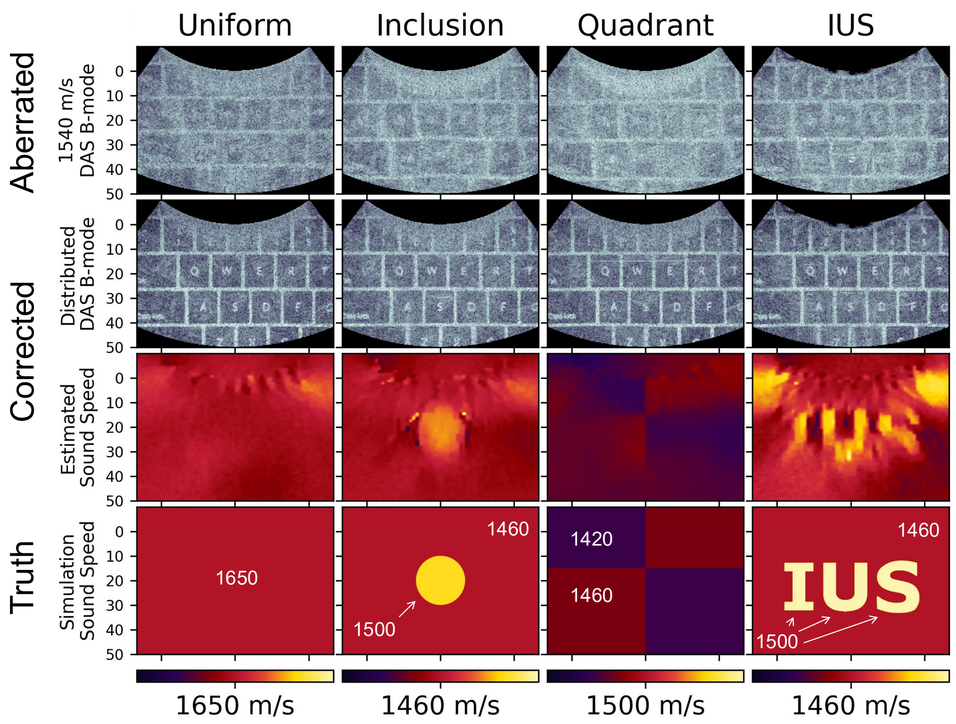
CNR increased by 0.16 ± 0.25



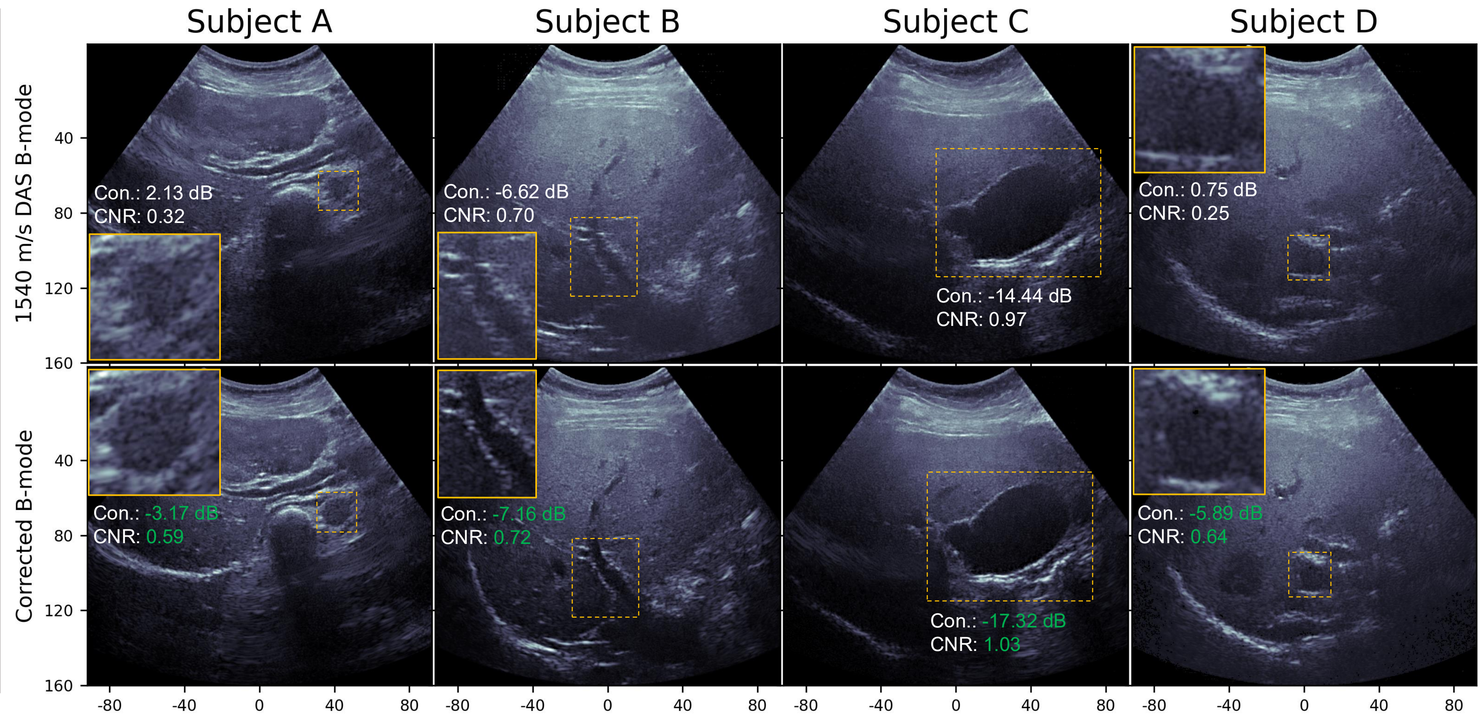
Global image quality metrics improved by an avg. of 5.12%



Simulation Results



In Vivo Human Liver Results



Summary and Acknowledgements

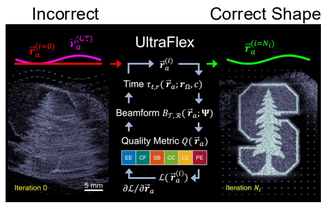
- We have designed and validated a differentiable beamforming model for distributed aberration correction that supports linear and curvilinear transducer arrays.
- We applied our model to in vivo human liver data from high-BMI subjects.
- In vivo contrast and CNR improved by 2.75 ± 3.28 dB, and 0.16 ± 0.25, respectively.
- Global image quality metrics all improved (CMPE, CMCC, SB, CF, LOC).
- Better metrics are needed to evaluate aberration correction via distributed sound speed estimation due to significant aberration variation between subjects.
- This work is funded by the NIBIB under Grant R01-EB027100.

References and Related Work

[1] Simson, W., Zhuang, L., **Frey, B. N.**, Sanabria, S. J., Dahl, J. J., & Hyun, D. (2025, Sep.). Ultrasound Autofocusing: Common Midpoint Phase Error Optimization via Differentiable Beamforming. *IEEE T-MI* (Manuscript awaiting publication).
[2] Huang, O., Long, W., Bottenus, N., … & Palmeri, M. L. (2020). Mimicknet, mimicking clinical image post-processing under black-box constraints. *IEEE T-MI*, *39*(6), 2277-2286.
[3] Brevett, T. (2024). QUPS: A MATLAB Toolbox for Rapid Prototyping of Ultrasound Beamforming and Imaging Techniques. *Journal of Open Source Software*, *9*(101), 6772.
Fryar, C. D., Carroll, M. D., & Ogden, C. L. (2018). Prevalence of overweight, obesity, and severe obesity among adults aged 20 and over: U.S., 1960–1962 through 2015–2016.
World Health Organization. (2022). *Obesity and overweight*. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

This Work
Frey et al. 2025. *IUS*.
Project Link
https://benfrey.com/ius2025

UltraFlex
Frey et al. 2025. *T-UFFC* (Under Rev.)



https://benfrey.com/ultraflex

DBUA
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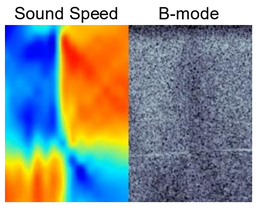

https://waltersimson.com/dbua

Spatial Gain Compensation
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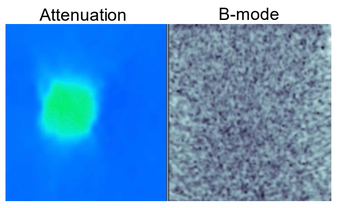

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