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Geometrical Acoustics based Focusing Methods in Medical Ultrasound

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Ultrasound imaging is a widely used non-invasive tool in modern medicine. For image formation, the time-of-flight between the acoustic sources and the image pixels needs to be calculated accurately. For this, the currently used standard focusing method assumes a constant sound speed in the observed medium. Using this method for non-constant sound speeds leads to blurred and geometrically shifted ultrasound images. In this talk, we compare three focusing algorithms for known layered media:

1. standard focusing method (assumes a homogeneous medium)
2. straight ray tracing (accounts for sound speed variations, but neglects Snell's law of refraction)
3. geometrical acoustics based focusing methods (account for sound speed variations and Snell's law of refraction) [1], [2]

While the standard focusing method assumes medium homogeneity, straight ray tracing improves image quality by using a more precise time-of-flight calculation method which accounts for sound speed variations. Snell's law of refraction, however, is neglected by straight ray tracing. Geometrical acoustics based focusing methods further improve upon this by additionally incorporating refraction effects, yielding accurate time-of-flight values [1], at the cost of increased computational complexity. We analyze under which conditions straight ray tracing provides sufficient accuracy and when refraction must be explicitly modeled.

Numerical simulations evaluate the precision of each method for time-of-flight calculation. Finally, we demonstrate the aberration correction potential of straight ray tracing and geometrical acoustics based methods using ultrasound images obtained in an experimental setting.

References

- [1] S. Hackl, S. Hubmer, and R. Ramlau: A Geometrical Acoustics based Focusing Algorithm for Layered Media in Medical Ultrasound. arXiv preprint arXiv:2510.05951 (2025).
- [2] C. Mineo, D. Cerniglia, and E. Mohseni, Solving ultrasonic ray tracing in parts with multiple material layers through Root-Finding methods, *Ultrasonics*, 124 (2022), p. 106747.952