# USCT Data Challenge

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## INTRODUCTION

Ultrasound Computer Tomography (USCT) is a technique that can be used for estimating acoustic properties of tissues from scattered pressure measurements. Two methods were applied with provided experimental data.

## METHODS

**(1) Diffractive tomography: First-order Born approx.**

$$\bar{f}^{sc} = \bar{B}^{r} \cdot D\left(\bar{f}\right) \cdot \bar{O}$$

$\bar{f}^{sc}$: Vector containing the scattered field measurements.

$\bar{B}^{r}$: Matrix of Green's function values.

$D\left(\bar{f}\right)$: Diagonal matrix of the incident field.

$\bar{O}$: Vector defined by: $k^2 - k_0^2$

**(2) Ray tracing**

$$R \cdot s = d$$

$R$: Matrix of ray distances within each pixel in the domain for each source-receiver pair.

$s$: Vector containing the difference between the slowness with and without the imaging target for each pixel.

$d$: Vector containing delays for each source-receiver pair.

Analyzed approaches:

- Straight ray propagation
- Refracted paths

Post processing: Total variation regularization.

**Data sets**

**1) 2D TU Delft USCT**

Sources: 45 (30 cm)

Receivers: 450 (10 cm)

Range of coverage: 360°

Transducer: Single element

Frequency: 0.5 MHz

Diameter: 0.75" 0 1.9cm

**2) 2D CSIC/UCM USCT**

Sources: 176 (20 cm)

Receivers: 450 (20 cm)

Range of coverage: 180°

Transducer: Linear array

Frequency: 3.5 MHz

Pitch: 0.22 mm

## RESULTS

**Data set 1**

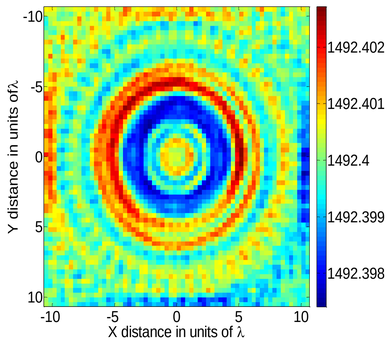


Fig 1. Reconstruction using diffraction tomography.

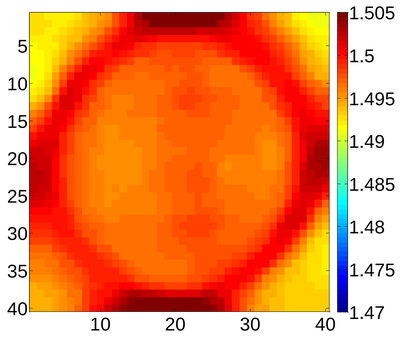


Fig 2. Reconstruction using straight ray tracing.

**Data set 2**

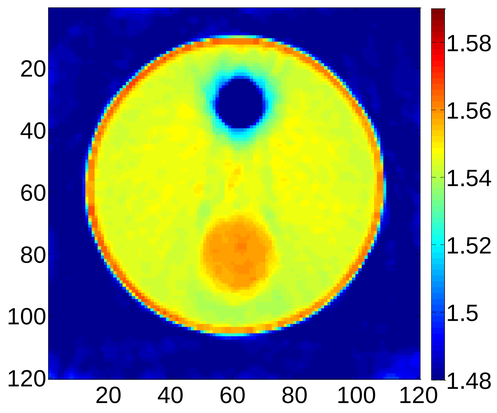


Fig 3. Reconstruction using straight ray tracing.

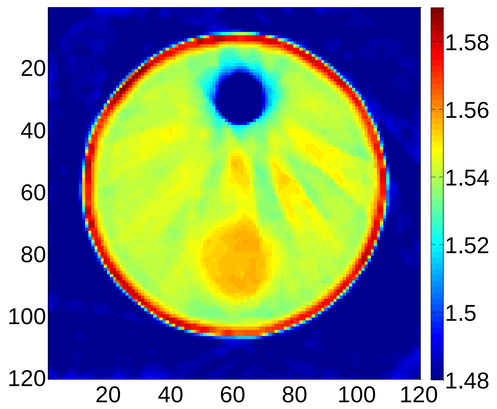


Fig 4. Sound speed reconstruction using ray tracing with refracted paths.

## DISCUSSION

**Limitations for diffraction tomography in data set 1**

1) Unawareness of the actual acoustic fields of transducers.

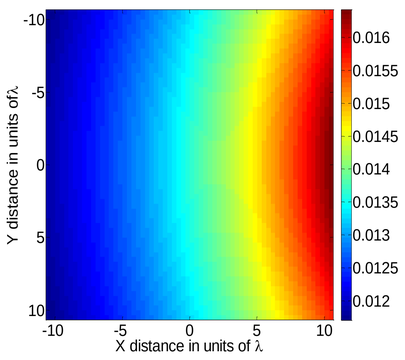


Fig 5. Ultrasound field of punctual sources

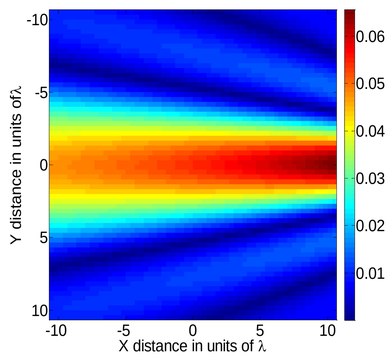


Fig 6. Ultrasound field of piston sources

2) Calibration factor: phase and magnitude

$$f_{\text{sc\_measured}} = f_{\text{sc}} \cdot \text{factor}$$

3) Noise level: 30 ~ 40 dB

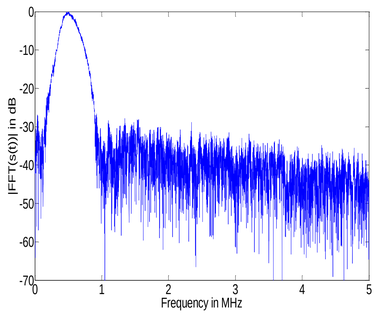


Fig 7. Dataset 1 SNR≈30 dB

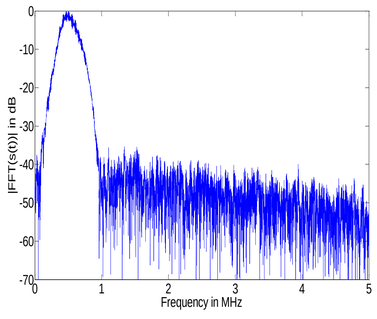


Fig 8. Dataset 2 SNR≈40 dB

## DISCUSSION (cont.)

4) Incident field cancellation: Incident field measurements lack perfect symmetry.

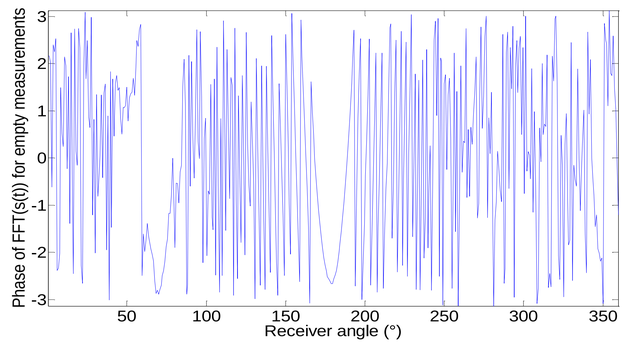


Fig 9. Phase of the Incident field measurements.

**Limitations for ray tracing in data set 1**

- 45 x 50 measurements could be used for reconstruction.
- Diameter of receivers ≈ 1.9 cm (≠ point transducers)

**Limitations for ray tracing in data set 2**

- Relatively large separation among receiver locations for the data acquisition → Non uniform polar paths.
- Inaccuracies in the slowness map used for ray tracing.

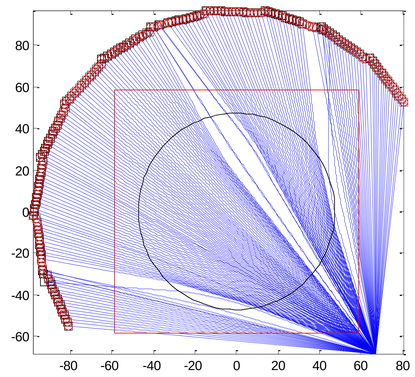

Fig 10. Example of ray tracing with refraction

## CONCLUSIONS

1. **This study tested two different approaches for reconstructing tomograms, (1) on the frequency domain, and (2) on the time domain.**
2. **It can be noticed how important the choice of instrumentation in data acquisition is to provide reconstructions with these algorithms.**
3. **Ray tracing method was successful for reconstructing tomograms in data set 2. However, small details such as needles were not observed in the reconstruction.**

## REFERENCES

1. R. Lavarello, and M. Oelze, "A study on the reconstruction of moderate contrast targets using the distorted born iterative method", in IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 55, no. 1, pp. 112-124, 2008.
2. L. Kinsler, A. Frey, A. Coppens, and J. Sanders, "Fundamentals of Acoustics," Wileys, 4th ed, 2000.
3. A.H. Andersen, and A.C. Kak, "Digital ray tracing in two-dimensional refractive fields", in J. Acoust. Soc. Am., vol. 72, no. 5, pp- 1593-1606, November 1982.

***This research was supported by grant 012-2014-FONDECYT-C1 from the Peruvian Government.***