LUNG ULTRASOUND ABERRATION CORRECTION WITH SINGULAR VALUE DECOMPOSITION BEAMFORMING AND PULSE-CODED EXCITATION

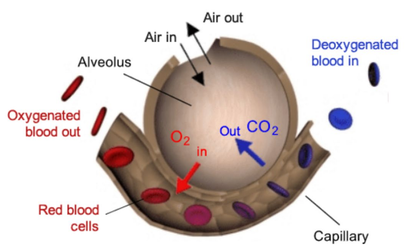
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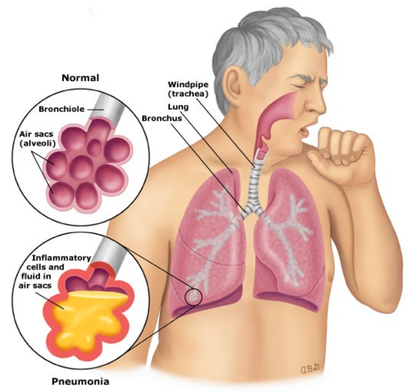
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INTRODUCTION

Background

The poor propagation of acoustic waves in air-filled tissues is a challenge for ultrasound imaging. The lung is composed of alveoli, which are tiny air-filled sacs at the ends of the bronchioles, responsible for the exchange of oxygen and carbon dioxide between the lung and the blood. The complex propagation phenomena in these tissues are translated into different image artefacts, and its mere appearance can be profited to diagnose different diseases. However, as information goes beyond anatomy and morphology, trained personnel is needed to interpret images.





Our proposal

In this work, We use singular value decomposition (SVD) [1] to perform fast aberration correction during real-time ultrasound imaging. The method mitigates aberrations from second-order random scattering allowing for ultra-fast imaging in lung tissue. In addition, we incorporate pulse-coded excitations to improve the signal-to-noise ratio and mitigate attenuation in lung tissue. The combination of aberration-free ultrafast imaging with pulse-encoded excitation has the potential to penetrate deeper in lung tissue, allowing its quantitative characterization by ultrasound. In this work, the performance of the above techniques is evaluated in a lung phantom, and safety tests were performed according to international recommendations.

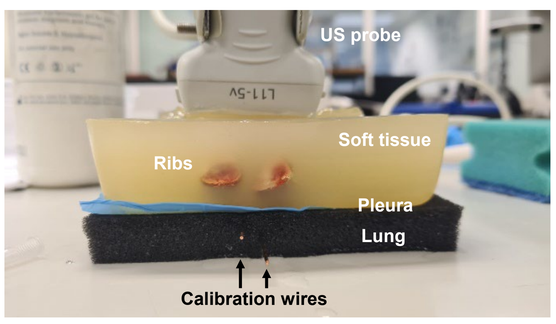
Lung phantom → Experimental (SSS) → Beamforming (SVD) → Analysis

METHODS

Materials

A lung phantom was manufactured using agar-gelatine to simulate skin and muscle tissue, pig ribs to simulate human ribs, a layer of nitrile to simulate the pleura and a triphasic porous structure (wet sponge) to simulate lung tissue. Copper wires of 0.1 cm were placed at different distances into the sponge to quantify the penetration of ultrasound.





A research imaging system (Vantage 256) was used for the ultrasonic measurements. Two probes were used. First, we used a 64-channel phased array imaging probe with a central frequency of 2.7 MHz and a bandwidth between 1.7 and 3.7 MHz and, second, a 128-channel probe using a central frequency of 7.5 MHz.

METHODS (Cont.)

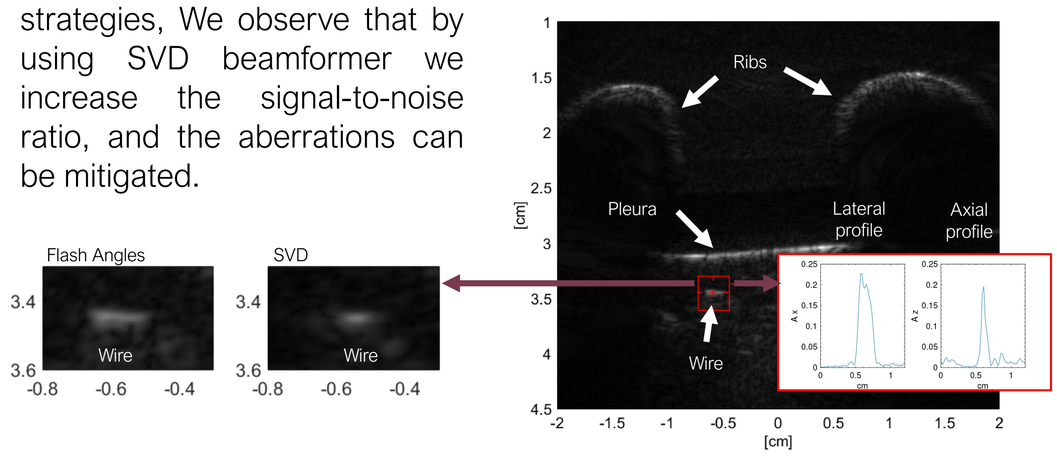
Methods

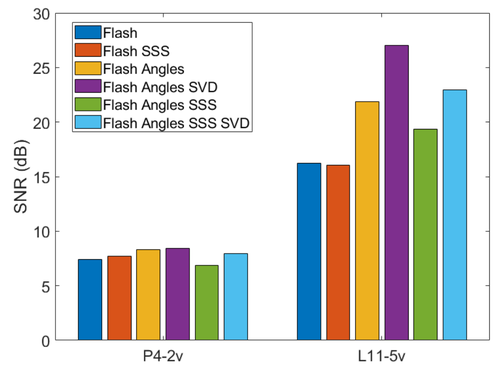
Two types of transmissions were used, a conventional short pulse and a synchronised sine sweep excitation [2]. On these two emissions, 3 types of beamforming approaches have been applied: planewave compounding, multiple planewave compounding, and multiple planewave compounding using SVD, where a total of 100 transmissions are emitted in an angular scan (-30º to 30º), the IQ image is formed for each of the receptions and an SVD is applied, to obtain an image capable of correcting the aberrations.

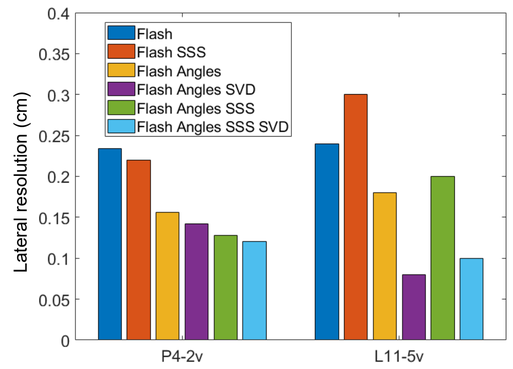
RESULTS

Results

We have performed a total of 12 tests with the same conditions as the phantom. By comparing the different beamforming and compounding strategies, We observe that by using SVD beamformer we increase the signal-to-noise ratio, and the aberrations can be mitigated.







CONCLUSIONS

Summary

Twelve ultrasound modalities has been developed and compared. Signal-to-noise ratio and lateral resolution was analyzed using the copper wires into lung-tissue phantom. The proposed methods increase image performance and penetration comparing with traditional approaches.

Impact

The results of this work open the possibility of retrieving valuable information from the microporous structure of lung tissue, allowing the use of quantitative ultrasound and elastography methods to evaluate lung tissue.

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REFERENCES

[1] Bendjador, H. The SVD beamformer: Physical principles and application to ultrafast adaptive ultrasound. IEEE Trans Med Imag, 39(10), 2020.

[2] Novak, A.,Synchronized swept-sine: Theory, application, and implementation. J Audio Eng Soc, 63 (10), 2015.

Lung Ultrasound (low penetration) → SSS pulse-codded (enhanced SNR) → SVD beamforming (low aberration) → Quantitative US (tissue evaluation) → Lung elastography (stiffness mapping)

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