

Ultrasound clutter suppression using local singular value decomposition

The high frame rates (>1000 fps) achievable with modern ultrasound scanners uniquely positions ultrasonic imaging for quantification of real-time blood flow as it occurs in the heart chambers. However, signal obtained from blood is far weaker than the surrounding tissue which interferes with blood motion estimation. The separation and removal of strong tissue signal from the blood signal is known as clutter suppression.

The problem

The standard techniques used for clutter suppression mostly assume a distinct separation in velocity ranges between tissue and blood. However, in cardiac applications this is often not the case, where the motion of the heart wall and valves frequently exceed the blood velocity.

Current solution (and the problem with this solution)

Recently singular value decomposition (SVD) has been used with great success in liver and brain imaging and is based clutter suppression (Demene et al., 2015). This technique works by decomposing a dataset into two matrices of singular vectors, sorted and ranked per their total energy values over the dataset. In the case of 2D/3D+time datasets, such as those in ultrafast ultrasound, this sorts the dataset by a combination of intensity and coherence over time. Thus, areas of the image with strong signal that are slow moving over time (tissue) are sorted to the first few singular vectors, and can be removed without removing blood signal. However, in the case of cardiac motion, the distinct changes in motion patterns over the cardiac cycle makes a single decomposition insufficient for all patterns of motion present.

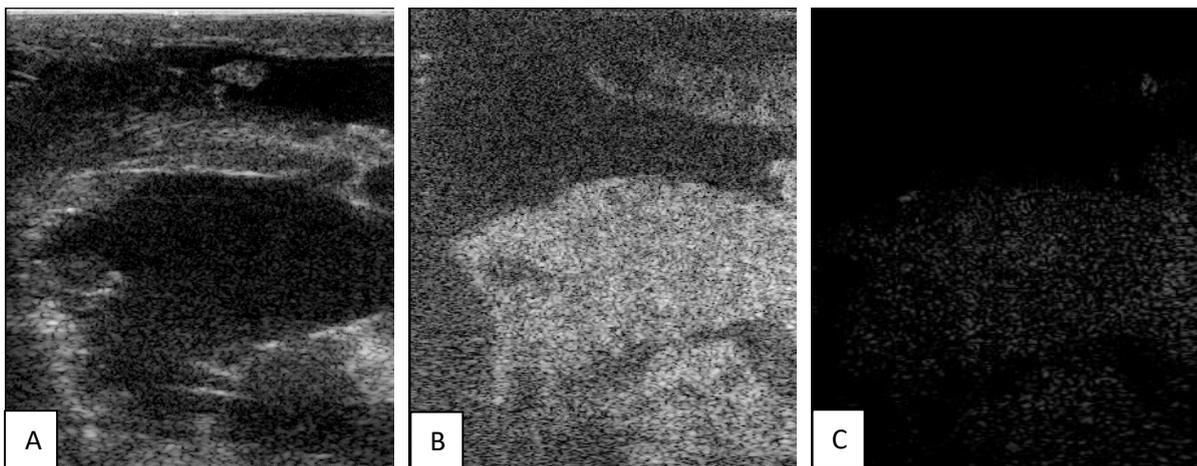


Figure 1: A) 2D ultrasound image of pig heart without clutter suppression. Note the relatively high signal intensity of tissue to blood pool. B) Global SVD clutter filtration during peak systole (fast flow) effectively removes tissue; however, C) during diastole (slow flow) the signal from both blood and tissue is removed. It is expected that a localized approach will perform better across all phases of the cardiac cycle.

The project

This project will investigate the application of a block-wise SVD, which analyses the full dataset in local blocks instead of all-at-once. This is expected to improve the separability of blood from clutter and noise. Some work has already been done to implement the block-wise SVD algorithm but the logic behind selection of the singular values to be removed is ongoing research and will be the primary focus of this study. *In-vivo* data is available for use.

Short outline of the project (6-9 months):

- Study of previous literature in the field (SVD and other clutter suppression techniques)
- Determination of effective singular value removal protocol for clutter and noise
- Determination of optimum block-sizing and recombination strategy
- Quantification of important signal characteristics (e.g. clutter-to-blood ratio and SNR)
- Comparison with standard SVD and other localized clutter suppression techniques (FIR/IIR)
- Write-up of Master's thesis

Requirements:

- Background in biomedical engineering, physics or similar
- Knowledge of imaging processing and signal processing techniques
- Programming experience in Matlab and/or Python

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References:

Demene, C., Deffieux, T., Pernot, M., Osmanski, B.-F., Biran, V., Gennisson, J.-L., ... Tanter, M. (2015). Spatiotemporal Clutter Filtering of Ultrafast Ultrasound Data Highly Increases Doppler and fUltrasound Sensitivity. *IEEE Transactions on Medical Imaging*, 34(11), 2271–2285. <https://doi.org/10.1109/TMI.2015.2428634>