Feasibility of 3D Clutter-Filtered Wave Imaging for Mechanical Wave Tracking in Arterial Walls

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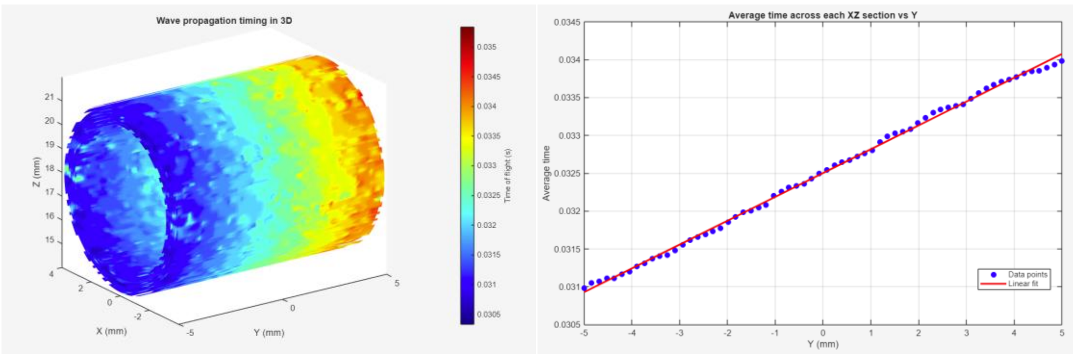
Pulse Wave Velocity (PWV) is used to assess vascular stiffness, a key predictor of cardiovascular mortality. Pulse Wave Imaging (PWI) is a non-invasive ultrasound-based technique enabling the tracking of these complex dynamics. While most PWI methods rely on two-dimensional assumptions, arterial motion is three-dimensional. In this work, the feasibility of a 3D clutter-filtering-based approach for tracking wave propagation along the arterial wall is investigated.

Simulated data were generated using the MUST toolbox. In this example, the vessel was modeled as a cylindrical structure with scatterers distributed within the wall. Mechanical wave propagation was simulated as a localized radial expansion of the vessel wall. Plane wave imaging was performed at a volume rate of 3000 volumes per second. The simulated IQ signals are beamformed using a delay-and-sum (DAS) algorithm, followed by voxel-wise temporal high-pass Butterworth filtering, envelope detection, and temporal differentiation to improve wavefront detection. For each voxel, the time corresponding to the maximum acceleration is identified representing the arrival of the wave at that point. Finally, arrival times are averaged over each cross-sectional plane of the vessel, and a linear regression of time versus propagation distance is performed, from which the pulse wave velocity is estimated as the inverse of the slope.

3D time-of-flight maps obtained for a simulated pulse wave velocity of 3 m/s are shown on the figure. The estimated velocity is (3.17 m/s). The method was evaluated for multiple velocities.



(a) 3D arrival times (b)Averaged arrival times as a function of propagation distance.

The proposed method demonstrates the ability to track the propagation of mechanical waves along a cylindrical vessel model. However, this configuration remains a simplified representation of vascular dynamics. Ongoing work focuses on validating the approach on in vitro data, with results to be presented.