C4D - Contextual 4D: An Intuitive 4D Visualization Framework for Flow Vector Projectiles and Tissue

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Background, Motivation and Objective

Recent breakthroughs in real-time 3D ultrasound imaging have sparked interest in visualizing blood flow in 3D at fine temporal resolutions. An intuitive visualization paradigm is needed to present the sonograph in an intuitive manner. The extension of 2D slice visualization to densely populated 3D space is non-trivial. Specifically, flow trajectories are concealed within vessel walls embedded in tissue structures. We suggest this can be overcome by prioritizing flow vector display and creating context by rendering the surrounding vessel and tissue with varying opacity. Here, we present Contextual 4D (C4D) - a framework that produces intuitive visualizations of both flow vectors and tissue in a 3D volume.

Statement of Contribution/Methods

C4D first establishes context by presenting the vessel geometry, and incrementally introduces detail in 3D space over time. Detail in the form of flow vector projectiles is revealed by reducing the opacity of surrounding features. In a C4D display, flow vector projectiles with speed coded to length and color are rendered to highlight trajectories. The vessel wall is then rendered opaquely and surrounding tissue is rendered as translucent B-mode slices. Over the course of display, more of the tissue slices and vessel wall are made transparent, gradually revealing the flow projectiles inside. After all flow projectiles are revealed, this process reverses until the entire vessel wall is opaque to create a complete visualization cineloop. C4D was tested on a dataset acquired from a helical toroid phantom (3mL/s constant flow) using a SonixTouch scanner equipped with a linearly scanned L14-5 array. This dataset contains two plane wave acquisitions (3 Tx°: -10°, 0°, 10°, 10kHz PRF, 5MHz freq) from two orthogonal scan directions. The velocities were derived using a vector Doppler estimator (UMB 2014; 40, 2295-2309).

Results/Discussion

Fig. a-c show a C4D visualization at different time points. Spatial context is established early by emphasizing vessel geometry in Fig. a. B-mode slices are made transparent as the visualization progresses (Fig. b), revealing more detail through flow projectiles. Eventually, nearly all flow vectors are presented (Fig. c). Overall, this framework can effectively balance context and detail to communicate flow information. C4D has strong potential to foster the adoption of 3D flow imaging in clinical settings.