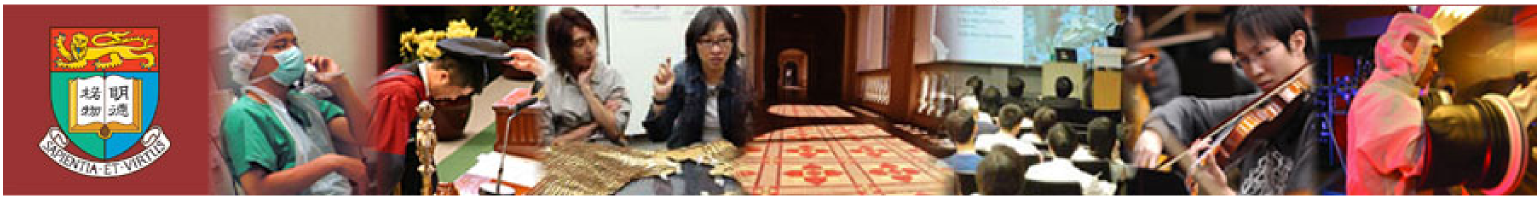

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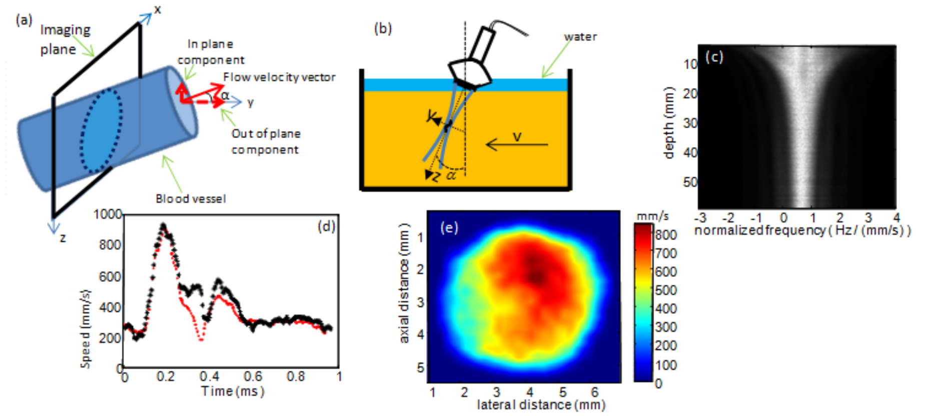

Figure: (a) Description of transverse imaging of a blood vessel, (b) Experimental set-up for the spectrum calibration, the imaging plane is orthogonal to the figure, (c) Example of calibration spectrum (α=4°), we notice that the DS width is varying with the depth due to the elevation focus of the probe, (d) Time speed profile obtained with the transverse (black) and the longitudinal (red) acquisition on a region of interest , (e) Two dimensional speed profile obtained with a transverse acquisition at the time 270ms.

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High-Frame-Rate Color-Encoded Speckle Imaging for Visually Intuitive Rendering of Complex Flow Dynamics

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Background, Motivation and Objective

Realization of flow imaging at high frame rates can undoubtedly benefit the visualization of complex flow patterns with significant spatiotemporal variations. It would be even better if fluid motion can be coherently rendered through parallel display of both flow trajectory and flow speed. Driven by these motivations, we have developed a new high-frame-rate ultrasound flow visualization technique called color-encoded speckle imaging (CESI). It provides a visually intuitive interpretation of complex flow through a hybrid display format that shows both flow speckle pattern and color-encoded velocity mapping.

Statement of Contribution/Methods

CESI works by integrating two key principles: 1) using broad-view data acquisition schemes to obtain image data at frame rates well beyond the video range; 2) deriving and displaying both flow speckles and velocity estimates from the acquired broad-view data. We have realized CESI on a channel-domain research platform that consists of a programmable transmit core (SonixTouch), a pre-beamformed data acquisition tool (SonixDAQ), and a high-performance GPU-array processor (for flow signal processing). Plane wave compounding was implemented (5 steering angles, ranging from -10 to +10 degrees), and these parameters were used: 10 kHz PRF (yielding 2000 fps frame rate for 5 steer angles), 3-cycle transmit pulse, and 7 MHz frequency. Speckle and velocity were estimated using a sliding window method and the lag-one autocorrelation algorithm. The performance of CESI was evaluated in the context of monitoring complex flow dynamics inside a carotid bifurcation flow phantom with 25% eccentric stenosis at the ICA inlet (developed via investment casting). Cineloops were generated in both the CCA and the bifurcation region.

Results/Discussion

With 2000 fps frame rate and parallel rendering of speckles and velocities, CESI was capable of visualizing various fast-changing flow dynamics (both spatially and temporally) in a stenosed carotid bifurcation with 72 bpm pulses. Not only was CESI able to track flow acceleration and deceleration, it was also effective in depicting flow jet formation and progression as well as the development of recirculation zones (see figure). These are new visualization features beyond what color flow imaging is capable of providing. They demonstrate that CESI can more intuitively render complex flow dynamics.