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Deep Learning to Resolve Aliasing in Color Flow Imaging

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Background, Motivation and Objective

Visualization of flow dynamics using color flow imaging (CFI) is known to be obscured by aliasing artifacts when slow-time signals are sampled below Nyquist limit. A general work-around is to first detect the aliased velocities and then apply correction factors to rectify the aliasing artifacts. To achieve this, precise segmentation is needed but existing techniques are unreliable *in vivo* due to poor signal-to-noise ratio. We hypothesize that when dealing with noisy environment, deep neural networks can be used to consistently segment and correct the aliased regions, and in turn improve complex flow visualization.

Statement of Contribution/Methods

We devised a dealiasing framework that consists of two algorithmic stages: 1) segmentation of aliased CFI pixels using a convolutional neural network based on a 31-layer U-net architecture (arXiv, 2015; 1505.04597); 2) adaptive dealiasing of segmented regions by comparing the values on the interior of the segmented regions with exterior pixels (Med Image Anal, 2011;15:577-88). The neural network was implemented using Python (3.6.7) and Keras (2.1.6-tf). It was trained with CFI frames acquired from a spiral phantom (T-UFFC, 2017; 64:1840-8) under 3 mL/s constant flow using a SonixTouch scanner (L14-5 array; 3.3 kHz PRF; 5 MHz freq. plane wave transmissions). Data augmentations were applied to generate 7132 CFI frames (1168 original) and aliasing artifacts were manually segmented to serve as training references. The performance of our framework was evaluated on a 50% stenosed carotid bifurcation phantom and an *in vivo* femoral bifurcation from a volunteer.

Results/Discussion

Our framework succeeded in dealiasing CFI frames of the carotid bifurcation phantom and the *in vivo* femoral bifurcation. In the carotid bifurcation phantom, 99% accuracy in classifying aliased pixels was achieved compared with manual segmentation. Fig. 1a shows the acquired femoral CFI at systole with aliasing artifact observed in the deep femoral branch. The trained U-net successfully identified the aliased region with high confidence (Fig. 1b) and upon dealiasing, flow speed that is beyond the Nyquist limit could be estimated (Fig. 1c). This framework holds promises as a new solution to resolve erroneous flow estimates due to aliasing. It is especially relevant to vector Doppler where aliasing would significantly affect vector estimation accuracy.

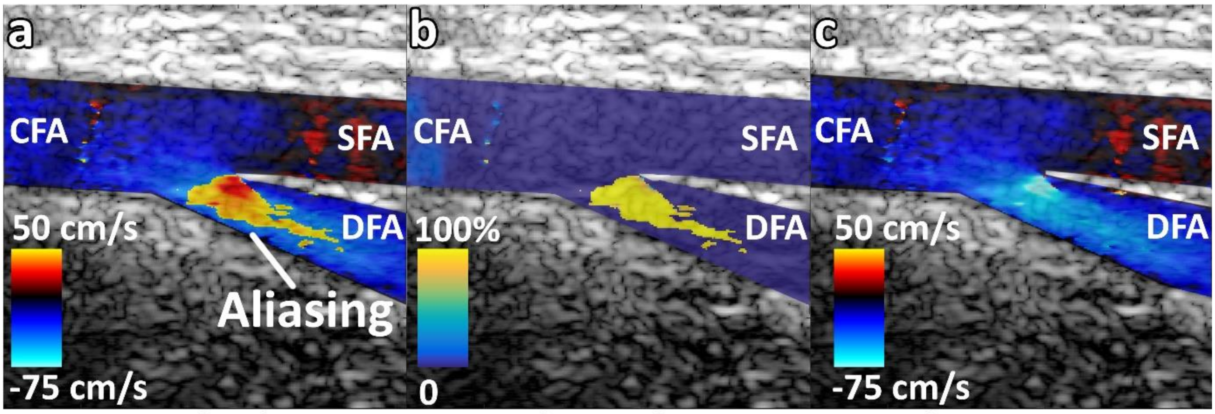

Fig. 1. Results of the framework on an *in vivo* femoral bifurcation, including the Common Femoral Artery (CFA), the Superficial Femoral Artery (SFA) and the Deep Femoral Artery (DFA). **a)** Original color flow image with aliasing artefacts in the lower branch. **b)** Aliasing segmentation confidence by U-net. **c)** Color flow image with the aliasing artefact removed by adaptive phase unwrapping.