# 4G - Vector Flow Imaging

Sapphire (220)

*Wednesday, October 24, 4:00 pm - 5:30 pm*

Chair **Enrico Boni**
University of Florence

**4G-1**

**4:00 PM**

## A fast 4D B-spline framework for model-based reconstruction and regularization in vector flow imaging

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**Background, Motivation, and Objective**
Ultrasound vector flow imaging (VFI) methods have shown promise for measuring intracardiac flow patterns, but are hampered by variance and clutter filter dropouts. Methods attempting to mediate often lead to feature blurring (smoothers) or scale poorly when moving to 4D imaging (model-regularizers). We propose a flexible reconstruction framework based on an efficient B-spline interpolation kernel and with model-based data regularization terms computed on the analytical spline gradients.

**Statement of Contribution/Methods**
A general purpose nD B-spline interpolator of arbitrary orders and differentials was developed in the open source TensorFlow framework. Sparse gradients supporting reverse mode automatic differentiation (AD) were implemented, enabling the use of stochastic gradient descent optimizers to minimize general differentiable cost functions even on memory constrained systems. This allows arbitrary models and data sources to be specified with a high level of implementation abstraction.  Parallel forward pass and AD codes were written for CPU and GPU to increase performance across platforms. The framework was evaluated for vector flow reconstruction constrained by the incompressible Navier-Stokes (NS) equations.

**Results/Discussion**
Evaluation was done towards a computational fluid dynamics (CFD) phantom, subjected to semi-realistic artifacts and noise. Measurements were fitted to 4D spline grids, penalizing the deviation from the NS momentum and mass balance at each data point. This resulted in convincing reconstructions for moderately challenging scenarios, example seen in figure, where the (reconstructed) lateral and total RMSE were 3.5 mm/s and 3.0 cm/s respectively. The average 4D reconstruction time of the phantom on a NVIDIA Titan V was 3 minutes. An observed limitation with this model is the lack of inlet/outlet handling, leading to underestimation of the true velocities in these regions when momentum balance is strongly enforced.  In vivo 4D data was acquired using a GE Vivid E95 system with a 4V probe, where VFI was done using 3D blood speckle tracking (BST), while the LV domain was extracted automatically using the open-source FAST library. We emphasize that the flexibility of the framework lies in the ease of specifying models and data sources, and its general purpose nature invites application to other regularization problems.

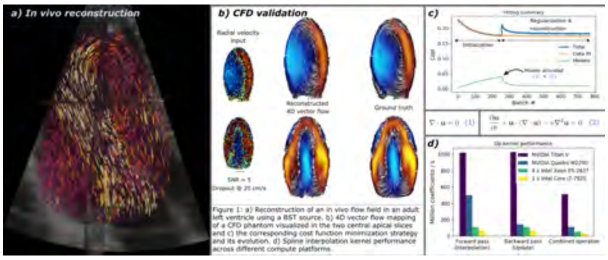


Figure 1: a) Reconstruction of an in vivo flow field in an adult left ventricle using a BST source. b) 4D vector flow mapping of a CFD phantom visualized in the two central apical slices and c) the corresponding cost function minimization strategy and its evolution. d) Spline interpolation kernel performance across different compute platforms.