Increasing the Dynamic Range of Velocity and Temporal Resolution of Particle Image Velocimetry

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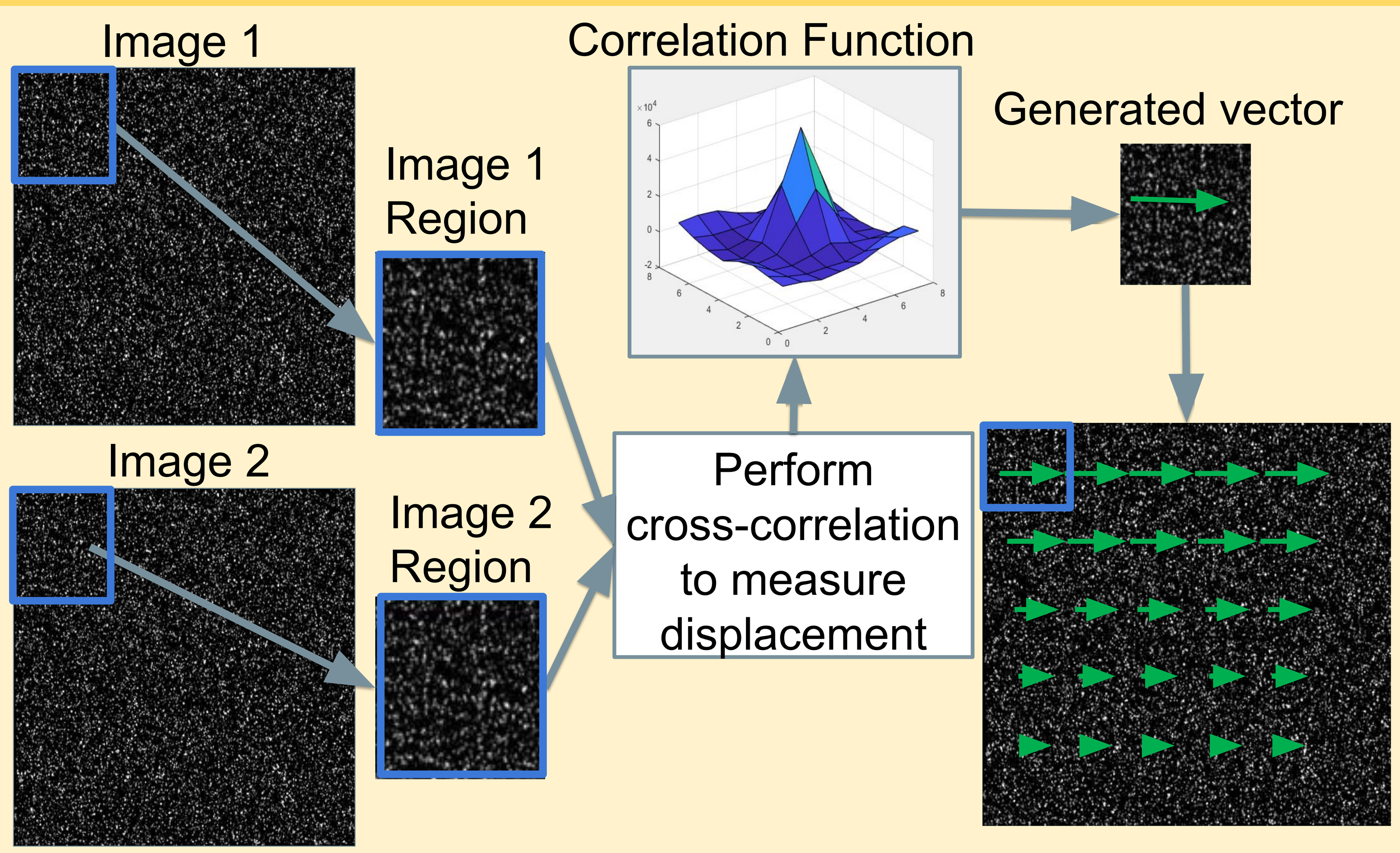
Abstract

Particle image velocimetry is a technique used to capture and measure the instantaneous velocity of a flow field. To further increase the dynamic range and temporal resolution of particle image velocimetry (PIV) measurements, a combination of two novel PIV image processing techniques called pyramid processing and vortex-in-cell. The pyramid processing technique evaluates the PIV data at progressively larger time separations in order to capture the movement of particles traveling at progressively slower speeds. The vortex-in-cell technique increases the temporal resolution of the data by performing interpolation in between each data point through the use of a vorticity based model.

Background - Standard PIV Image Processing

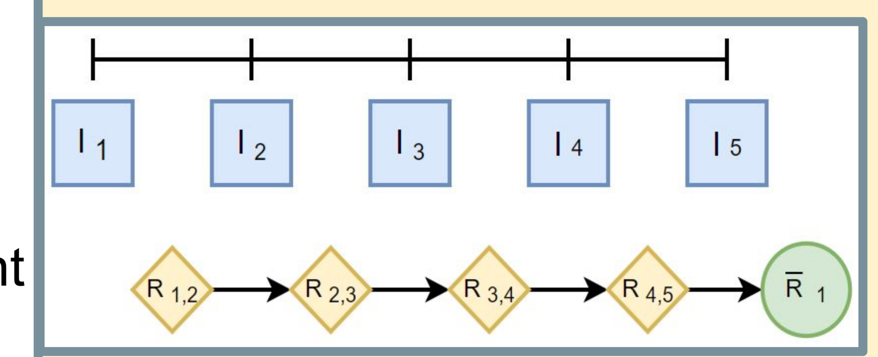


Background - Vortex-in-cell (VIC) Temporal Supersampling

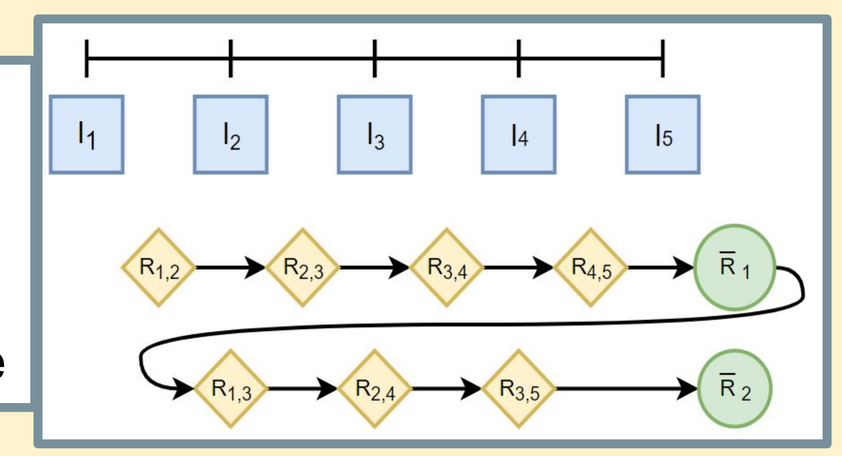
- Particle motion in between frames iteratively interpolated using vorticity based model
  - Particle voticities found with particle position and a third order symmetric interpolation function
  - Vorticity used to find stream function calculated using Poisson solver
  - Flow velocity field then derived from stream function and used to advect particles. The process then repeats

Background - Pyramid Processing

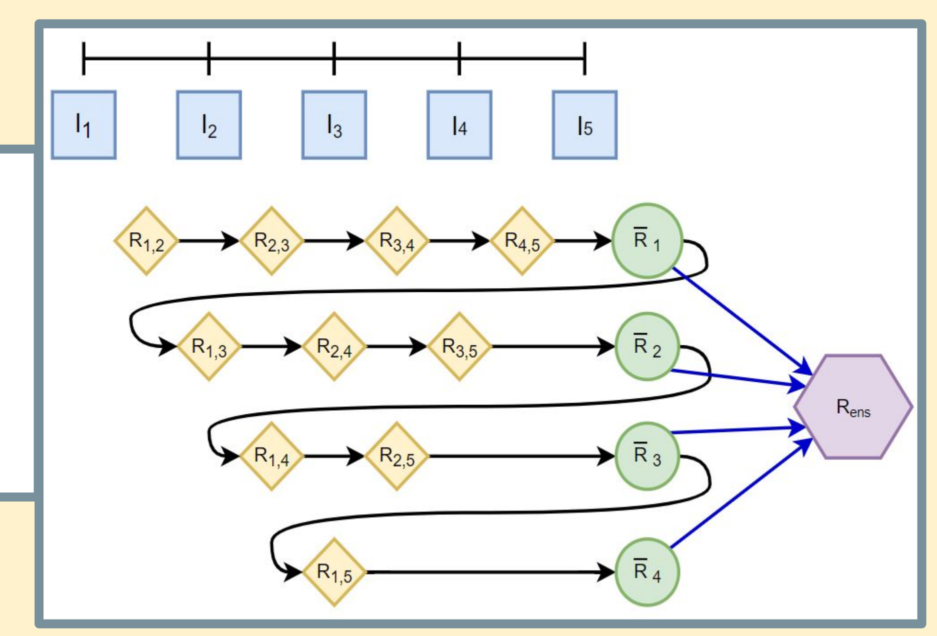
Collect long set of images spaced equally in time and evaluate image pairs (R) sequentially and average resulting particle displacement maps together for "layer averaged displacement map"



Repeat averaging of image pairs at Δt=2 and so on, allowing slow particles to be analyzed and fast moving particles to move out of frame



Once slowest moving particles observed, layer averaged maps scaled to same coordinate system and averaged together



Conclusion / Future Work

- Pyramid processing provides improvements over standard PIV analysis techniques at low velocities
- Addition of VIC should further improve resulting velocity fields

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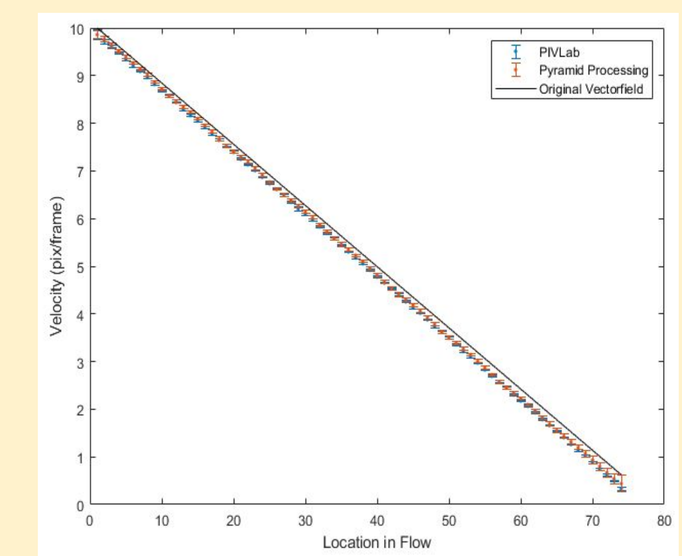
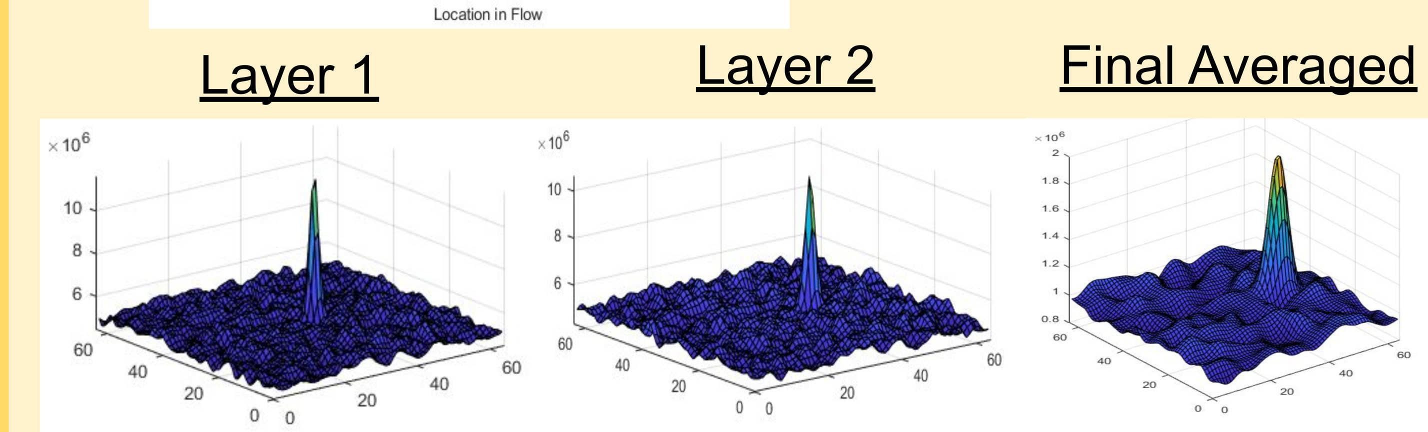
Results

Laminar Shear Flow

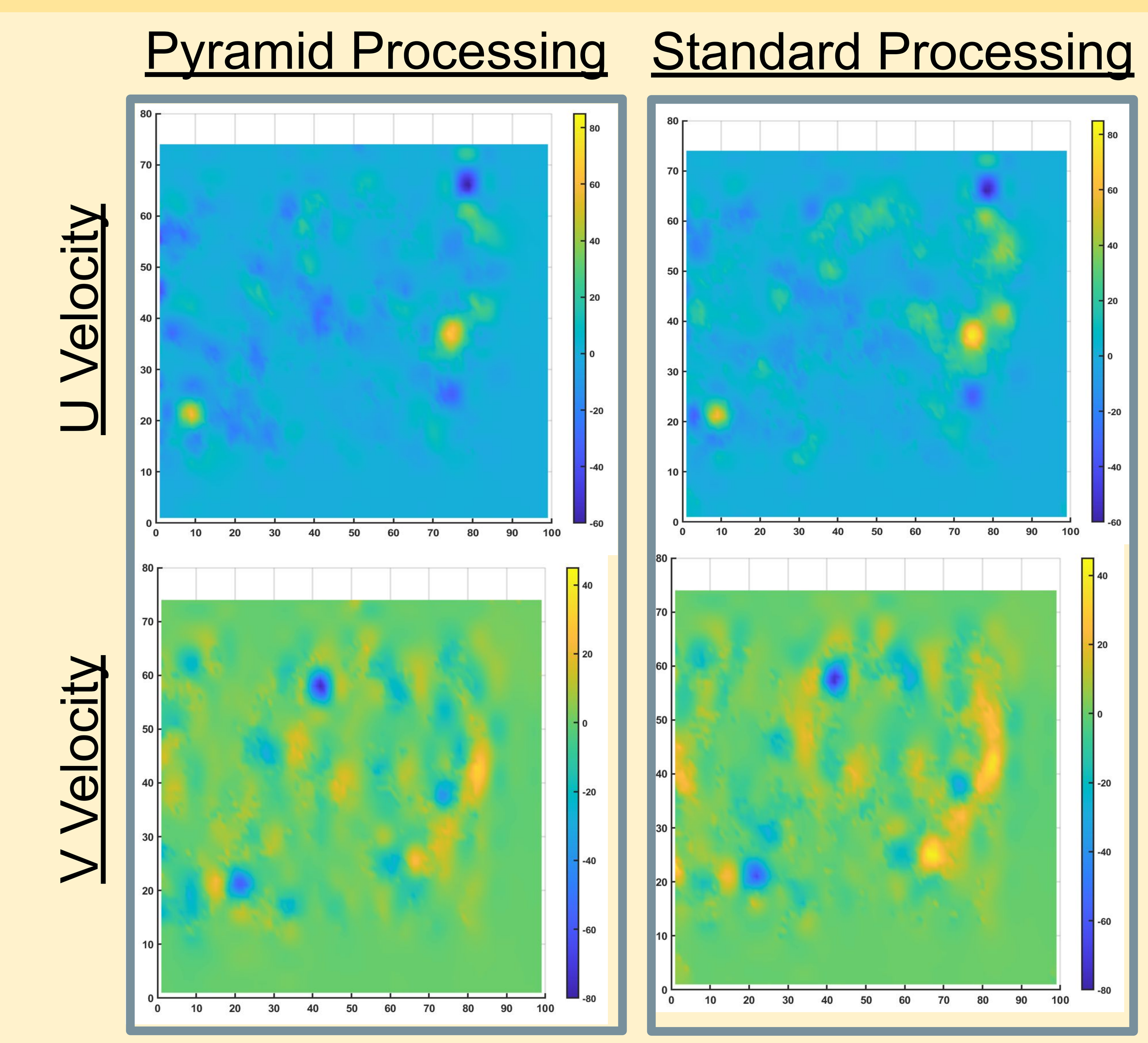


- Decrease in reconstruction error by <1% in fast moving flow and ~10% in slow moving flow



- Displacement map peak shift forward as Δt increases
- Averaged map has wide base and sharp peak

Turbulent Flow



- Decrease in reconstruction error of ~10% in slow moving regions and ~2% in fast moving regions for both U and V velocities
- Largest improvements found near vortices

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