Volumetric PIV with a Plenoptic Camera and Scanning Laser

EE 367: Final Project Proposal – Valerie Troutman <vtrout@stanford.edu>

Motivation

A single camera, simple 3D volumetric, portable imaging system is needed to fully capture the 3D components of various fluid phenomenon in the ocean.

For most physical flows, the third dimension is critical to capture, but collecting the third dimension experimentally poses many challenges. Synchronizing multiple cameras is a common solution for this problem, but is costly and for our application, very bulky. Another solution is to sweep a laser sheet through a volume, capturing multiple pictures throughout the illuminated volume. The images are combined to reconstruct the volume, but the frame speed of the camera limits the speed in which you can collect the full volume, and you need to record the location of the laser sheet throughout the sweeping pattern.

Current plenoptic 3D PIV work is limited by the size of the volume that can be captured. The volume reconstruction is limited by the width of the laser sheet, the power of the laser spread over the volume, and the resolution of the plenoptic camera.

Related Work

3D PIV with Plenoptic Camera

3D PIV has been done with a plenoptic camera, with a very small volume (67 mm x 39 mm x 45 mm and 61mm x 91 mm x 100 mm) resolved [Thurow 2013].

The same group has published papers regarding the volumetric reconstruction [Fahringer 2012 & 2013].

Scanning Laser 3D PIV

A laser light sheet was scanned by an optical scanner in a direction normal to the sheet, and two high-speed cameras captured the particle images [Hori 2004].

Project Overview

Particle image velocimetry (PIV) is a technique that utilizes the particles suspended in a fluid to understand the velocity field of the flow.

Plenoptic imaging (or light field imaging) collects the 4D light field of a scene by placing a microlens array in front of the sensor of a CCD camera. The collected image is processed to generate multiple new images where the focus depth and perspective are different.

This work aims to combines these two technologies in order to perform 3D PIV using a laser, spinning mirror and a plenoptic camera. The laser will sweep through the volume of interest during the exposure time of the camera. The collected image will be processed to reconstruct the volume

of particles. That volume will then undergo PIV algorithms to ultimately have the velocity field of the particles.

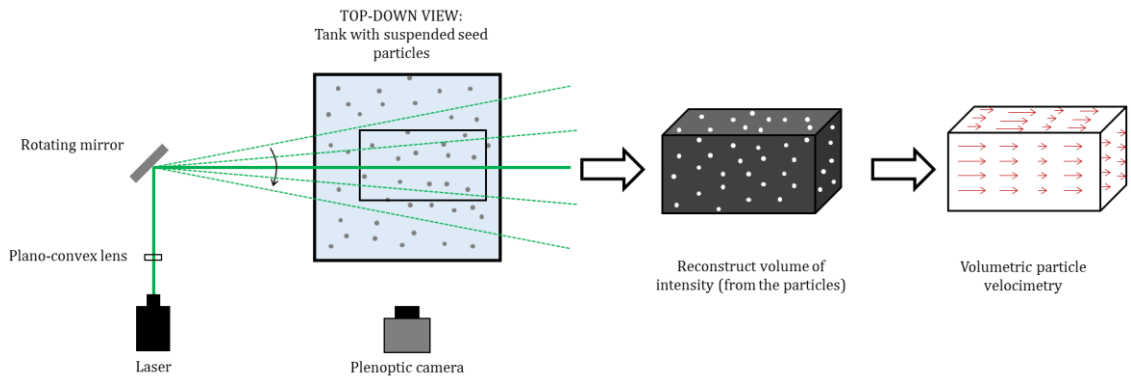

Figure 1: Proposed volumetric PIV with a plenoptic camera and scanning laser

A 3D calibration tool will be used to verify the precision of the depth measurement. Sharp edges will be created by columns at multiple known depth locations.

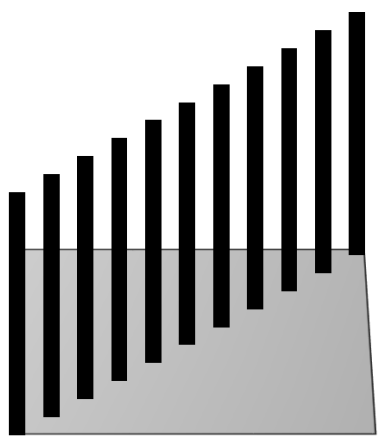

Figure 2: Proposed plenoptic camera depth calibration tool

One of the biggest challenges currently faced for 3D plenoptic PIV is the computational demands of reconstructing the volume. If overcoming these challenges are not solvable on the time scale of this project, the reconstruction will be limited to a fraction of the collected data. This will provide a proof-of-concept for the proposed diagnostic. Future work could expand the computational speed via optimization or super computer capabilities.

Milestones & Timeline

Week 5	2/1 – 2/5	Preliminary Images
		Literature Review
Week 6	2/8 – 2/12	Start to build processing code
		Order Items for Calibration Tool
Week 7	2/15 – 2/19	Build Depth Calibration Tool
		Start Poster
Week 8	2/22 – 2/26	Take final images
		Start Report
Week 9	2/29 – 3/4	Add in calibration to processing code
		Finish Processing/Analysis
		Finalize Figures
Week 10	3/7 – 3/11	Final Review/Edits for Poster & Report
		3/9 – Poster Presentation
Finals	3/14-3/18	**3/14 – Project Report Due**

References

[Thurow 2013] → Thurow, B. S. and Fahringer, T. W. "Recent Development of Volumetric PIV with a Plenoptic Camera," 10th International Symposium on Particle Image Velocimetry (2013)

[Fahringer 2012] → Fahringer, T. W. and Thurow, B. S. "Tomographic Reconstruction of a 3-D Flow Field Using a Plenoptic Camera," 42nd AIAA Fluid Dynamics Conference (2012)

[Fahringer 2013] → Fahringer, T.W. and Thurow, B.S. "The Effect of Grid Resolution on the Accuracy of Tomographic Reconstruction Using a Plenoptic Camera," 51st AIAA Aerospace Sciences Meeting (2013)

[Hori 2004] → Hori, T. and Sakakibara J. "High-speed scanning stereoscopic PIV for 3D vorticity measurements in liquids," Meas. Sci. Technol. 15 (2004) 1067-1078