Supplementary Material for "Full Volume 3D Fluid Flow Reconstruction with Light Field PIV"

This supplementary material includes: 1) an ablation study on the correspondence term, 2) additional flow reconstruction results on real captured data, and 3) comparison with other flow estimation algorithms on the real data.

1 Ablation on Correspondence Term

We perform an ablation experiment to show that the correspondence term in our flow estimation algorithm helps improve the particle matching rate. To demonstrate the effectiveness of the correspondence term E_{corres}, we conduct an ablation study: for a simulated vortex flow with density at 0.025, we extract two consecutive frames and match particle correspondences with vs. without E_{corres}. The matching results are shown in Fig. 1. We can see that using the correspondence term greatly improves the matching accuracy.

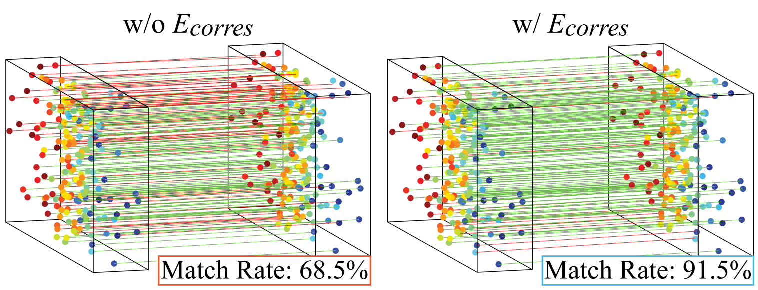

Figure 1: Particle matching between source and target volumes with vs. without using the correspondence term E_{corres}. In the plots, green lines indicate correct correspondences and red lines indicate incorrect ones. Particles are shown with color-coded depths.

2 Additional Results on Real Data

In the real experiment, we capture three different flow sequences. Here we show the flow reconstruction results on the other two sequences. Fig.2 shows the vector field reconstruction and path line visualization of the estimated flow. We compare the results of using only front view, only side view, and both views. We can see the fusion results are better than only using one view.

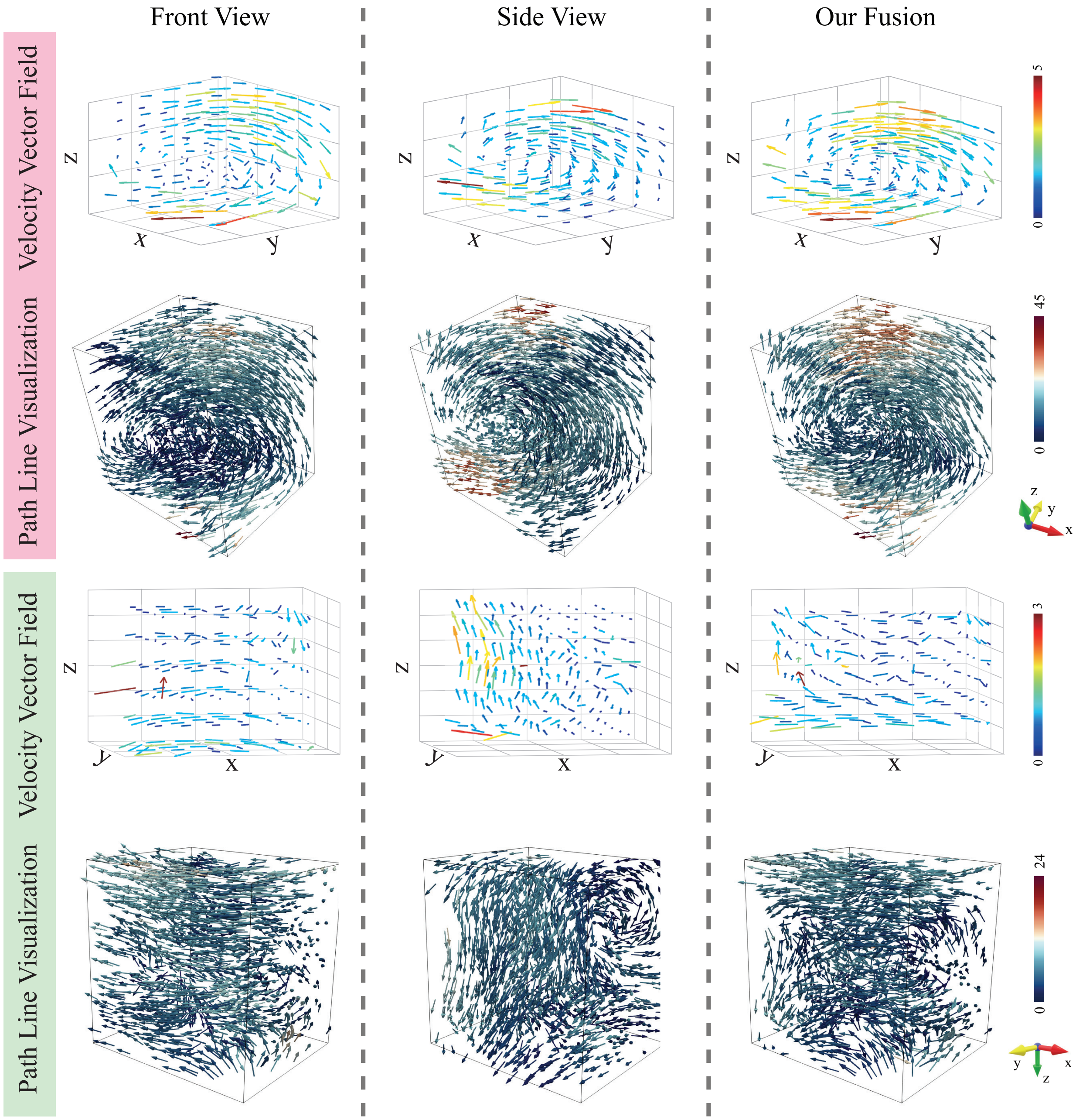

Figure 2: Additional real experiment results on two flows. We show the vector field reconstruction and path line visualization of front view, side view and two-view fusion.

3 Additional Comparisons on Real Data

We compare our method with the scene flow algorithm [1]. The method takes two consecutive RGB-D images as inputs and uses rigidity transform network and flow network for motion estimation. Since the method also needs depth map as input, we first calculate a depth map for the center view of light field and then combine the depth map with the sub-aperture color image as input for [1]. For fairness, we only use our single-view solution in this comparison. The flow estimation results are shown in Fig. 3. We show the projected scene flows and the flow vector field. The scene flow method fails to recover the flow structures, especially for vortex flows. This is because our particles are heavily occluded and have very similar appearances. Further, the scene flow algorithm does not take the physical properties of fluid into consideration.

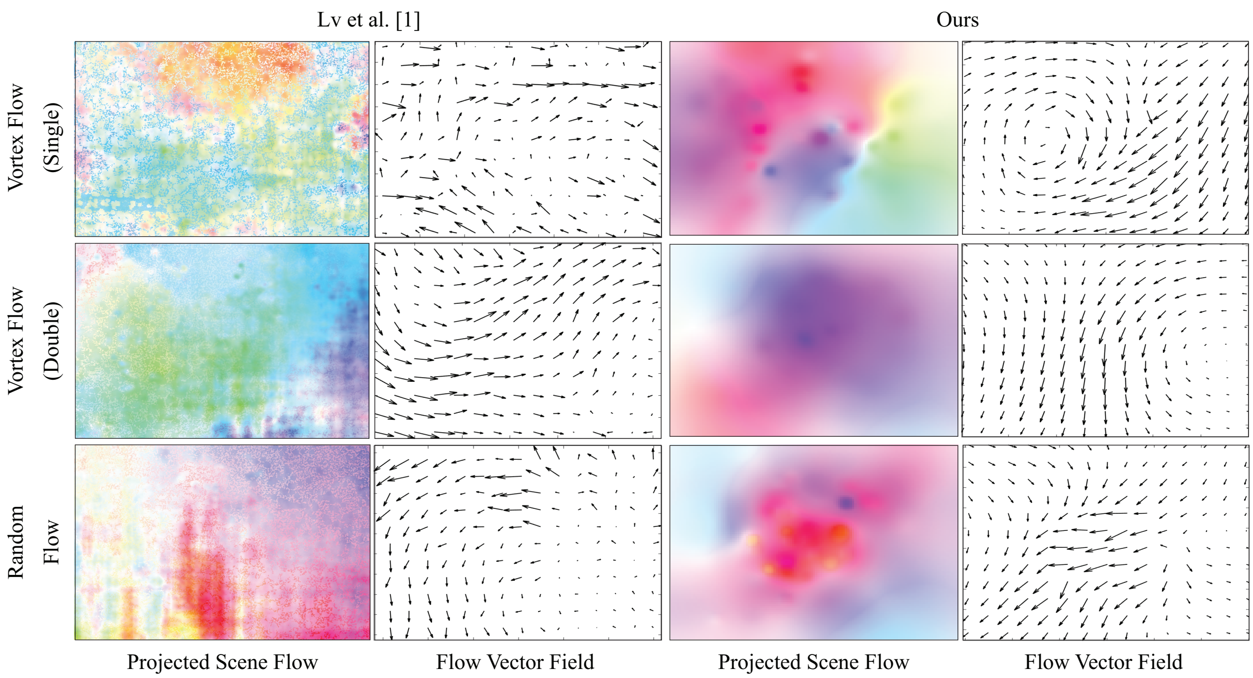

Figure 3: Comparison results with scene flow (Lv *et al.* [1]) on real data. We compare the projected scene flow and the flow vector field on three types of flows.

We also compare our method with two other state-of-the-art PIV methods: OpenPIV [2] and Zhang and Piggott [3]. OpenPIV [2] is an open source PIV software that performs cross-correlation among particle images. Zhang and Piggott [3] is a recent learning-based which is claimed to achieve comparable performance as the classical PIV. The method is trained on simulated particle image pairs. In our experiment, we directly use their pre-trained model. Comparison results are shown in Fig. 4. The experiment is performed on a single vortex flow. Although we do not have the ground truth to compare with, we can see that our reconstruction better represent the vortex flow.

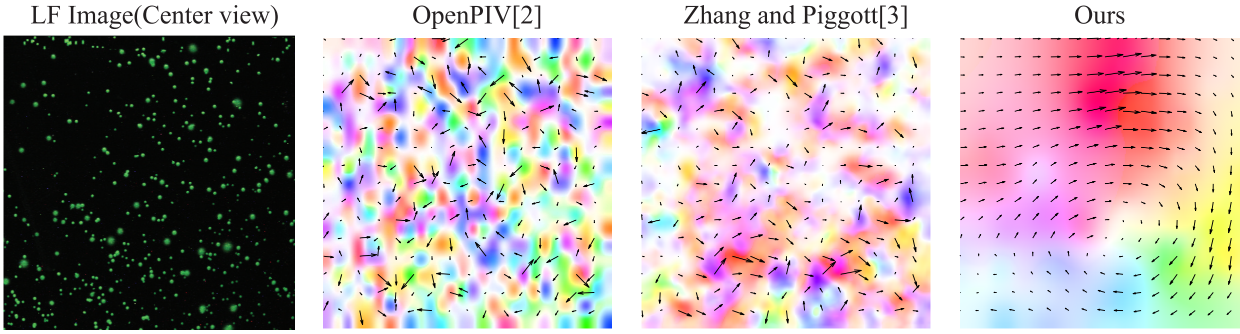

Figure 4: Flow reconstruction results on real data in comparison with other state-of-the-art PIV methods.

References

[1] Z. Lv, K. Kim, A. Troccoli, D. Sun, J. M. Rehg, and J. Kautz, "Learning rigidity in dynamic scenes with a moving camera for 3d motion field estimation," in *Proceedings of the European Conference on Computer Vision (ECCV)*, 2018, pp. 468–484.

[2] A. Liberzon, T. Käufer, A. Bauer, P. Vennemann, and E. Zimmer, "OpenPIV/openpiv-python: OpenPIV-Python v0.23.4," 2021.

[3] M. Zhang and M. D. Piggott, "Unsupervised learning of particle image velocimetry," in *International Conference on High Performance Computing*. Springer, 2020, pp. 102–115.