3D Tomographic Reconstruction of Dynamic Gas Bubbles from Dual-Perspective Imaging

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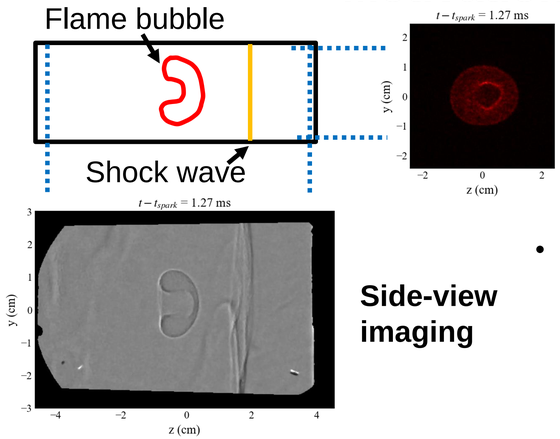
Motivation

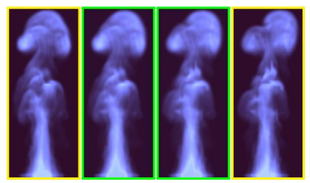


End-view imaging

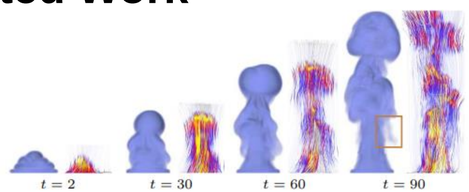
Side-view imaging

- Shock wave interaction with a flame bubble is important for supersonic combustion and astro-physics
- 3D reconstruction of the bubble geometry during the interaction aids the understanding of the underlying fluid dynamics
- Limited optical access means sparse-view tomographic reconstruction is needed

Related Work



[3]



[3]

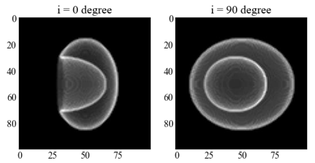
- Sparse-view computed tomography (CT) has been explored by many in medical imaging using compressive sensing (e.g., [1]) and deep learning (e.g., [2])
- Zang et al. recently performed sparse-view 3D reconstruction of fluid flow using optical-flow-based view interpolation [3]

References

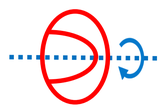
[1] Chen et al., Medical physics, 35, 660-663, 2008
[2] Han et al., IEEE transactions on medical imaging, 37, 1418, 2018
[3] Zang et al., ICVF, 1870-1879, 2020

Methods

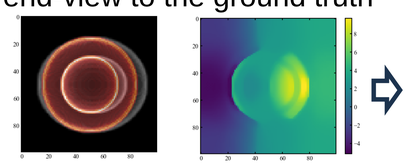
side/end views of a model bubble:



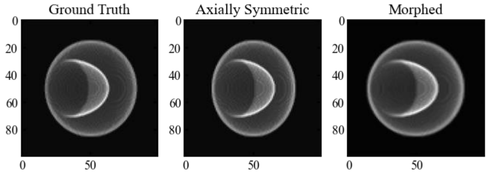
Revolve side-wall image



Optical-flow from revolved end-view to the ground truth



Synthesized view at 45 degree



Loss function for data fitting:

$$L_{data} = \sum_i ||K_i x - f_i||_2^2$$

K_i: Radon transform at angle i
x: 3D object
f_i: view projections

Optical-flow-based view synthesis:

$$\tilde{f}_j = \text{warp}(f_{r,j}, \sin(j)\, v_{end})$$

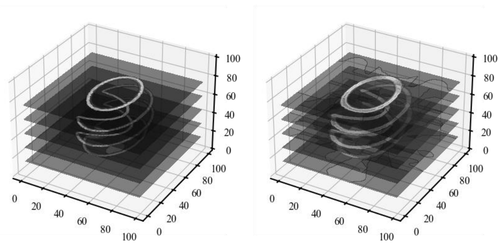
$\tilde{f}_j$: synthesized projection at angle j
$f_{r,j}$: revolved object projected at j
v_{end}: optical-flow velocity calculated from end-view images

Regularizer construction:

$$L_{TV} = \lambda_{TV} \nabla x$$

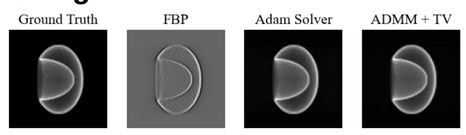
$$L_S = \sum_j^M \lambda_S ||K_j x - \tilde{f}_j||_2^2$$

Results



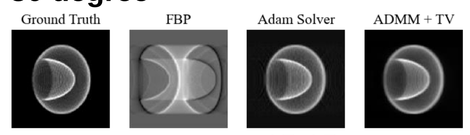
Ground Truth **ADMM+TV**

0 degree



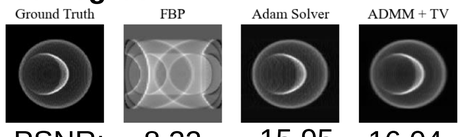
PSNR: 8.83 19.80 23.12

30 degree



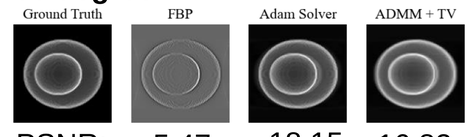
PSNR: 8.42 15.15 16.04

60 degree



PSNR: 8.22 15.95 16.04

90 degree



PSNR: 5.47 18.15 16.82

Horizontal cross-section slices from different methods