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Visualization challenge for measuring 3D3C velocity of air flow by using rainbow PTV technique

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SUMMARY
We try three-dimensional particle visualization for measuring 3D3C velocities of air flow by using a rainbow particle tracking velocimetry (PTV). Rainbow PTV can measure 3D3C velocity vector distribution with only single color camera and simple data processing. However, this technique has been applied only to small scale liquid flow with restriction for tracer particles: the PTV needs larger size tracer compared with convectional PIV. In the present study, we use helium filled soap bubble (HFSB), which has 300 μm diameter and close density to air. We confirm that the tracer bubbles can be captured, and their three-dimensional positions can be obtained in 25 cm scale air field. On the other hand, scale and dynamic range of measurement are limited by tracer size and light source intensity, indicating that larger size density-controlled tracer and higher intensity LCD projector are required for larger scale field measurement and higher velocity wind tunnel measurement.

Keywords: 3D3C rainbow PTV, gas flow, Helium filled soap bubble

1. INTRODUCTION

Measuring 3D3C velocity distribution for wind tunnel and field experiment can obtain more detailed vortex structure than 2D2C velocity PIV/PTV measurements in the focal plane but faces difficult problems. Scanning and tomographic PIV (Casey et al., 2013) and PTV with shake-the-box (Schanz et al., 2016) can measure 3D3C velocity distribution. These methodologies need multi cameras and complex data processing. Rainbow PTV (Watamura et al., 2013; Noto et al., 2021) can measure 3D3C velocity distribution with only single camera and simple data processing. The LCD projector as a light source output rainbow color pattern and illuminated particles were captured from diagonal direction to color changing direction. Particle depth position was calculated from degree of hue of particle color. However, this methodology has been applied only to liquid flow with restriction for tracer particles. PTV measurement needs larger tracer compared to PIV, but material of larger trace must have density close to flow. Helium filled soap bubble (Schneiders et al., 2016; Caridi et al., 2017) tracer has 300 μm diameter and density close to air. In this study, applicability of rainbow PTV to air flow with HFSB tracer is confirmed by a visualization test.

2. METHODOLOGY

2.1. Experimental Setup

Schematic diagram of experimental setup is shown in Fig. 1. Helium filled soap bubbles (HFSBs) tracers were seeded from a HFSB generator (LaVision GmbH). HFSB has 300 μm diameter, close density to air, and short response time tens of μs (Faleiros et al., 2019). Tracer bubbles were illuminated by an LCD projector VPL-HW60 (Sony), its intensity was 1900 lm. A Fresnel lens is fixed at the front of the projector to make illumination light telecentric. The width of color variation, in other words, depth of measured area are 25 cm. Tracer bubbles were captured by 3CMOS color camera AP-3200-PMCL (JAI) in the diagonal direction of projector light. 3CMOS can obtain RGB values on same pixel. Picture size is 2064 x 1544 pixels (x and y direction), field of view of x direction changes with depth from 194 mm to 306 mm, so spatial resolution is from 94 to148 μm/pix. A lens VS-1218/3CMOS (VS Tech) for color camera was used. The illuminated bubbles are captured at no artificial flow condition. The shutter speed is set 1 ms as minimum order in this setup.

(a) Top view (b) Overview

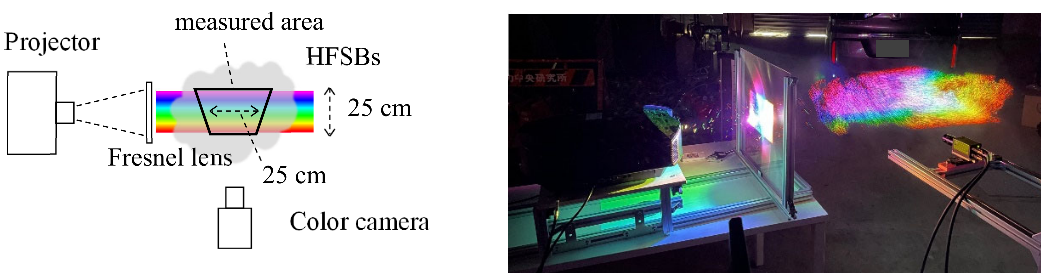

Figure 1. Experimental setup (a) Top view of schematic diagram, (b) Picture of overview

2.2. Data Processing

Positions of images in camera view (x and y) are determined through the same process as 2D2C monochrome PTV. R, G, B values of particles are extracted at particle positions, then degrees of hue, H are calculated with this equation (1) (Watamura et al., 2013).

$$H = \begin{cases} 60 \times \frac{G-B}{max(R,G,B)-min(R,G,B)} & (\text{if } max(R,G,B) = R) \\ 60 \times \frac{B-R}{max(R,G,B)-min(R,G,B)} + 120 & (\text{if } max(R,G,B) = G) \\ 60 \times \frac{R-G}{max(R,G,B)-min(R,G,B)} + 240 & (\text{if } max(R,G,B) = B) \end{cases} \quad (1)$$

Degrees of hue are converted to depth position (z) with a look up table. Unit of position in x and y are converted from pixel to mm using z position because field of view changes with depth, then three-dimensional particle positions are obtained.

3. RESULTS

A sample of captured image is shown in Fig. 2 (a). Image of illuminated bubble is very different from image of solid tracer in liquid. Same color two images are parallel in light direction, and their distance is 3 to 5 pixels. Fig. 2 (b) is conceptual drawing, there are two images on one illuminated bubble at front and back of the projector. Two images sometimes have very different degree of hue. The cause of this difference is uncleared, so in that case, the particle is excluded as error.

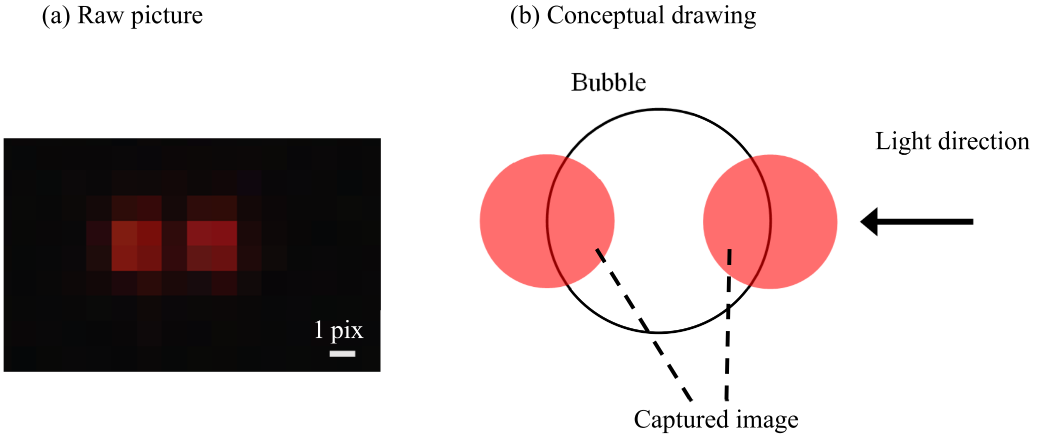

Figure 2. Captured two images of illuminated one HFSB (a) conceptual drawing, (b) example of raw picture

A sample of picture and result of data processing are shown in Fig. 3. Fig.3 (a) is a part of raw picture. The intermediate points of two images of one bubble are determined as the particle positions in camera view. Two degrees of hue are calculated by equation (1), and the averages of two degrees are regarded as hue degree of the tracers. Then, recognized tracers and their color with same size and brightness are plotted in Fig. 3 (b). Three dimensional positions are decided with color, and tracers are plotted in 3D domain shown in Fig. 3 (c).

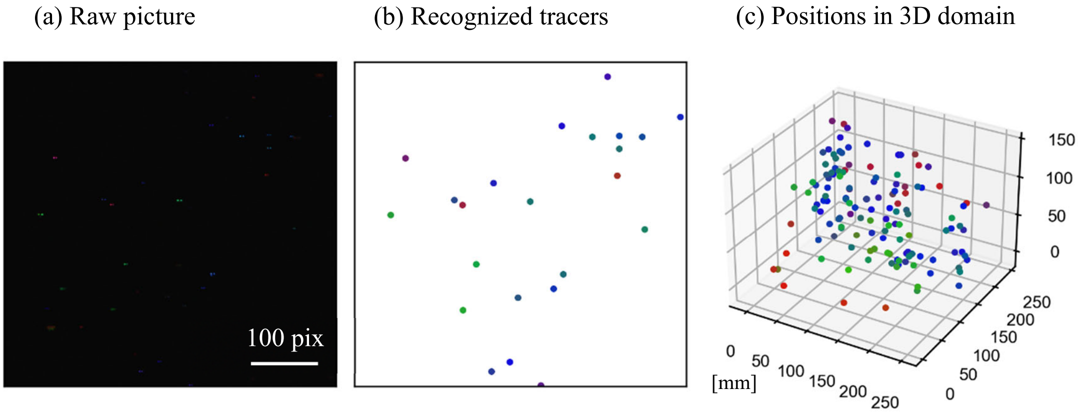

Figure 3. Data processing and an example of results (a) raw picture, (b) recognized particles, (c) particle positions in 3D domain

4. CONCLUSIONS

In the present study, we use HFSB tracer in 25 cm scale air field for visualization test of rainbow PTV. Contrary to solid particle tracer, there are two images on one bubble. Colors of two images are sometimes very different, then further investigation of its cause and treatment is required. It is confirmed that the tracer bubbles can be captured, and their three-dimensional tracer distributions can be obtained. A minimum shutter speed to recognize tracers for 25 cm field of view is order of 1ms. Scale and dynamic range of measurement are limited by tracer size and light source intensity, indicating that larger size density-controlled tracer and higher intensity LCD projector are required for larger scale field measurement and higher velocity wind tunnel measurement.

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REFERENCES

Caridi GCA, Sciacchitano A, Scarano F., 2017. Helium-filled soap bubbles for vortex core velocimetry. Exp Fluids 58:1–12.

Casey TA, Sakakibara J, Thoroddsen ST., 2013. Scanning tomographic particle image velocimetry applied to a turbulent jet. Phys Fluids 25.

Faleiros DE, Tuinstra M, Sciacchitano A, Scarano F., 2019. Generation and control of helium-filled soap bubbles for PIV. Exp Fluids 60:1–17.

Noto D, Tasaka Y, Murai Y., 2021. In situ color-to-depth calibration: toward practical three-dimensional color particle tracking velocimetry. Exp Fluids 62:1–13.

Schanz D, Gesemann S, Schröder A., 2016. Shake-The-Box: Lagrangian particle tracking at high particle image densities. Exp Fluids 57:1–27.

Schneiders JFG, Caridi GCA, Sciacchitano A, Scarano F., 2016. Large-scale volumetric pressure from tomographic PTV with HFSB tracers. Exp Fluids 57:1–8.

Watamura T, Tasaka Y, Murai Y., 2013. LCD-projector-based 3D color PTV. Exp Therm Fluid Sci 47:68–80.