ABSTRACT:

The acquisition of both spatially and temporally resolved experimental data is one of the greatest challenges in solving real-world fluids engineering problems. Accurate experimental data is vital in order to develop useful models for, and assess the accuracy of, numerical simulations and design tools. Time-resolved, volumetric observational techniques that deliver highly accurate experimental data for unsteady hydrodynamic flows can provide critical insights for the design and understanding of a wide range of systems that operate in the marine environment, including surface ships, submarines, undersea projectiles, offshore oil platforms, and ocean energy systems. To meet this compelling need, we have developed a new time-resolved, three-dimensional velocimetry method, based on light-field imaging and synthetic aperture refocusing methodologies. The novel three-dimensional, three-component (3D-3C) Light Field PIV method uses a multi-camera array to resolve volumetric flow fields, such as vortex rings and multiphase flows. Light Field PIV system represents the next generation of 3D PIV techniques and can have significant impact on the community due to the relatively low cost of image reconstruction and the ability to resolve densely seeded flow fields, to image near deformed interfaces, and to see through partial occlusions such as those found in multiphase flows. Spray flows can be optically dense, with a mix of fluid features such as ligaments and droplets.

This talk will demonstrate the versatility of lightfield PIV with results from two unique applications: briefly presenting 3D imaging of biological human sneeze spray flows and then looking more closely at aquatic propulsive wakes behind maneuvering and jumping Archer fish. Archer fish (genus Toxotes) exhibit multi-modal prey capture strategies combining spitting, rapid in-water pursuit, and jumping to feed in competitive environments. These fish can successfully jump to capture prey located several body lengths out of the water. Archer fish initiate jumps from directly below the surface and zero initial velocity, leaving limited space (one body length) to accelerate before fully exiting the water. The biomechanics and hydrodynamics of the fin and body motions for propelling, steering, and stabilizing the fish must be understood in order for engineers to replicate these aquatic launches. Results from 3D PIV studies on live jumping archer fish over a range of jump heights will be discussed in the context of propulsive performance.

Figure: (a) 9-camera Light Field PIV array; (b) instantaneous image of a sneeze spray; (c) 3D reconstruction of a maneuvering fish wake.