Understanding the Pectoral Swimming of Fish Using a Low-Cost Particle Tracking Velocimetry (PTV) Setup

Jayman Cannataro[1], Jaime Wong[1] & Ahmed Samir Ead[1,2]
1 Department of Mechanical Engineering, University of Alberta, Edmonton, Alberta, CANADA
2 Department of Biomedical Engineering, University of Alberta, Edmonton, Alberta, CANADA

A study from World Wildlife Fund Canada showed that all 167 of Canada's sub-watersheds were degrading in quality in 2017 due to industrialization, mining, and climate change, which can greatly affect the behaviour of fish. Changes in water flow can favour certain types of swimming which can alter the natural balance and wellbeing of an aquatic ecosystem. However, most studies on fish locomotion have focused on large-amplitude tail motions. As such, minimal focus has been placed on the study of pectoral swimming (e.g., for low-energy station-keeping and the exploitation of water flow to catch prey). To further understand the extent of these impacts, the swimming mechanics (e.g., fluid wake, fin kinematics, and thrust generation) of pectoral swimming must be studied. Particle image velocimetry (PIV) and particle tracking velocimetry (PTV) have been used to investigate the velocity field around the fins of live fish specimens, but were almost exclusively applied to thunniform models (large strokes of a tail fin) and anguilliform models (undulation of an entire body for propulsion). Pectoral swimming has been seldom investigated in literature. However, the small amplitudes and lower speeds associated with pectoral swimming may permit a wider range of measurement tools. For this application, a low-power system that can be run from battery power is attractive for field-adjacent measurements. Despite the wide applicability of PIV, the high cost of the equipment, the danger associated with high powered light sources being shone on live specimens, and the limitation to two-dimensional analysis often make it an inaccessible tool. Accordingly, the goal of this project is to develop and validate a low-cost PTV system that will allow for the three-dimensional velocity and vorticity analyses of pectoral swimming mechanics, providing a critical understanding of the relationship between pectoral swimming organisms and their changing aquatic environments.

The current camera setup is shown in Figure 1 and Figure 2. It uses commercial, off-the-shelf components as well as open-source software. The four-camera configuration is referred to as a 'quadrascope.' Currently, a preliminary calibration has been performed in LaVision DaVis (the RMS fit for each camera is 0.294, 0.331, 0.364, and 0.382 for the four cameras). The maximum resolutions and framerates (25 fps at 5120x800, and 100 fps at 2560x400) have been successfully identified as a part of an undergraduate research program at the University of Alberta. A validation study is being performed on an underwater, rotating wing. The results from the new PTV system will be validated using a conventional PIV setup.

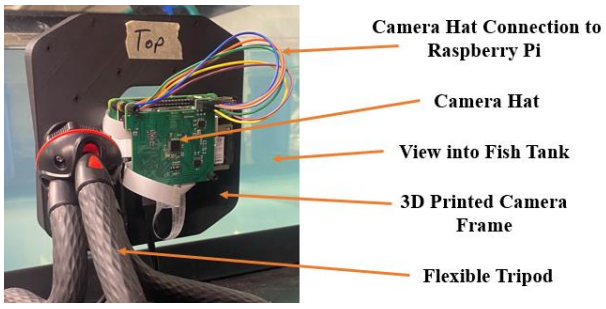

Figure 1: Quadrascopic Camera Array Facing into Fish Tank

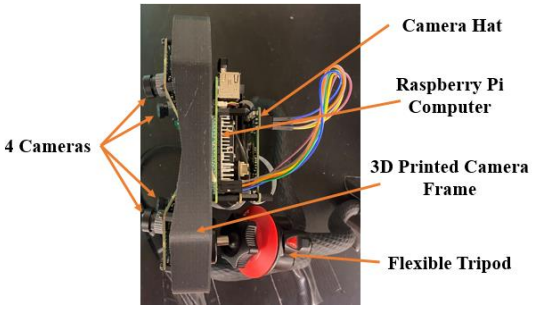

Figure 2: Top View of the Quadrascope

Email address for correspondence: *jayman@ualberta.ca*