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Data-driven modeling of fish rheotaxis: a multisensory feedback control approach

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Abstract: Millions of years of evolution have endowed animals with refined and elegant mechanisms to orient and navigate complex environments. Elucidating the underpinnings of these processes is of critical importance not only in biology to understand migration and survival but also for engineered network systems to aid the development of bio-inspired algorithms for estimation and control. Particularly interesting is fish rheotaxis, which is the innate ability of fish to orient and swim against a current. Empirical evidence suggests that rheotaxis is a multi-sensory process integrating multiple cues, such as vision and hydrodynamics. Little is known, however, about the information pathways and the integration process underlying this complex behavior.

This talk will discuss a novel data-driven mathematical model of adult zebrafish swimming in a flow, which contributes insight into the mechanisms underlying rheotaxis. The mathematical model leverages potential flow theory, stochastic differential equations, and control theory to describe rheotaxis as a multisensory feedback control process. Experimental data on adult zebrafish swimming in a water tunnel is used to calibrate the model and validate its predictive power. The model reveals that a simple yet effective hydromechanical feedback mechanism plays a critical role during rheotaxis. The results suggest that integrating data-driven research and dynamical system theory constitutes a viable approach to understanding the mechanisms underlying animal behavior and paves the way towards designing bio-inspired control solutions for the next generation of engineered network systems.

Bio: Daniel A. Burbano Lombana is a Provost Faculty Fellow in the Department of Mechanical and Aerospace Engineering at New York University, NY. His research interests include modeling, inference and control of complex systems with particular attention to problems in data-driven modeling of behavior, bio-inspired control, collective animal behavior, and distributed network systems. He received his Ph.D. in Computer and Control Engineering from the University of Naples Federico II, Italy (2015), and a M.S.c degree in Industrial Automation from the National University of Colombia (2012).