Numerical modelling of fish collective motion under visual perturbations

Many living systems exhibit fascinating dynamics of collective behavior during locomotion, from bacterial colonies to human crowds. The emergence of such complex spatio-temporal patterns can be described using local, short-range interactions between nearest neighbours. Fish schools are a typical example of this kind of self-organization: in order to perceive the position or kinematics of close neighbors, fish rely essentially on vision and sensing of hydrodynamic disturbances. However, the role of each of these senses is not clearly elucidated today.

Our objective is to model the visual interaction within a group of animals experiencing a dynamic visual disturbance (temporal variation of the ambient light intensity). Previous experiments have revealed a correlation between illumination and group cohesion, measured in terms of geometric parameters (polarization, rotational moment, nearest-neighbour distance) [1].

The goal of this internship is to study this behaviour using mathematical models of collective motion. Numerical simulations could elucidate the influence of illumination on the field of view of the fish (distance or angle of the cone of vision), and the role of density in the emergence of strong rotational motion when increasing light intensity (see Figure B. and C.) The model used will be a variation of the Persistant Turning Walker model, a system of coupled ordinary differential equations in which each fish's angular velocity evolves in time due to alignment with its closest neighbors, attraction towards the group, and random perturbations [2].

Depending on the student’s interests, it will be possible to go back and forth between models and experiments according to the needs of the project. The multidisciplinary co-supervision is an opportunity to work at the interface of experimental physical sciences and numerical modeling in mathematics.

A. The model organism used is a small gregarious tropical fish, *Hemigrammus rhodostomus* – B. Collective rotational motion of ~50 fish under high illuminance – C. Experimental results of rotational moment (M) and polarization (P) for a one hour experiment with illuminance variation (E) on 53 fish.


Expected skills: The student should have a solid background in the field of Ordinary Differential Equations (ODEs). He or she should also have good programming skills, in Python or in Matlab, as well as a strong interest in modeling and multidisciplinary interactions.