Long-range effects of walls in schooling fish

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Collective motion occurs when a system of self-propelled units exhibit spontaneous ordered movement. It is ubiquitous in the real world, arising in systems of many different scales. Here, we approach the topic considering fish schools.

One major challenge is to capture and quantify the interactions that drive the movement, both at the individual and collective level. This includes the cooperation between individuals and the responses to external elements, such as the presence of walls in a tank. Few works have tried to address the interactions with the walls, most of them investigating schools of only one or two fish1-4, finding short-range interactions decaying exponentially.

Here we aim to analyse quantitatively the experimental interactions of schooling fish with the tank walls and use this information to build a random walk model reproducing some key features of the system.

1 Experimental interactions

For the force of each wall we assume: 

\[ \vec{F}(\theta, y) \]

We work with \( m \equiv 1 \), so \( \vec{F} = \vec{q} \).

2 Fitting procedure

Ansatz: \( \vec{d}(\theta, y) = \Theta(\theta) Y(y) \). We exploit the symmetry of \( \theta \) adding a mirror trajectory of \( -\theta \) and follow a least-squares estimation for \( \Theta(\theta), Y(y) \).

3 Modeling trajectories of fish

We model trajectories of schooling fish and find the MSD matches the experimental trajectories.

Our school consists on 40 black neon tetra (Hyphessobrycon herbertaxelrodi) freely swimming in a shallow tank (5 cm of depth).

Three independent segments were recorded of 10 minutes of duration (1200 frames each).

The trajectory of individual fishes was digitized using a custom-made tracking software built in Python.

For each of the four walls, we define the coordinates of a fish relative to the wall \((x, y)\) and its orientation \(\theta\). In order to reduce the effects of the other walls, we discard all data points for which the center of mass of the school is outside the nearest central region of the wall (blue dashed rectangle).

Conclusions

- Wall forces in a fish school are long-range, in contrast with experiments of one or two fish.
- We model trajectories of schooling fish and find the MSD matches the experimental trajectories.
- Manuscript in preparation.

References:


