

Fish Swarm Dynamics

CS 302 – Modelling and Simulation

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Introduction

- Collective behaviour exhibited by animals to aggregate together.
- Common goal achieved by local rules leading to a self-organized behaviour
- Perceived circular surroundings modelled by multi-agent system.
- Decentralized system



Extended Craig Reynolds' Model

Rules

Basic Model^[1]:

- Collision avoidance: Avoid collision with neighbors
- Velocity matching: Align with the general direction of neighbors
- Flock centering: Go to the perceived center of the neighboring fishes

Extensions:

- Species (color) segregation: Only look at the neighboring fishes of the same species (color) when it comes to going to the center of the flock.
- Predator avoidance: For prey fishes, avoid the predator fishes with utmost priority
- Prey locking: For predator fishes, lock to the center of the neighboring prey fishes with utmost priority.

¹Reynolds, "Flocks, Herds, and Schools: A Distributed Behavioral Model".



Vicsek Model

Rule

- **Only 1 Rule**^[2] : At each time step a given particle driven with a constant absolute velocity assumes the average direction of motion of particles in its neighborhood of radius r with some random perturbation added.

$$x_i(t+1) = x_i(t) + \vec{v}_i(t)\Delta t \quad (1)$$

$$\theta(t+1) = \langle \theta(t) \rangle_r + \Delta\theta \quad (2)$$

$$\Delta\theta \sim \mathcal{U}\left(\frac{-\eta}{2}, \frac{\eta}{2}\right) \quad (3)$$

Total parameters: r, η, v, L, N

Reduced parameters: $\eta, \rho(= N/L^2)$

²Vicsek et al., "Novel Type of Phase Transition in a System of Self-Driven Particles"



Vicsek Model

Flocking parameter ν_a

$$\nu_a = \frac{|\sum_{i=1}^N v_i|}{N|v|} \quad (4)$$

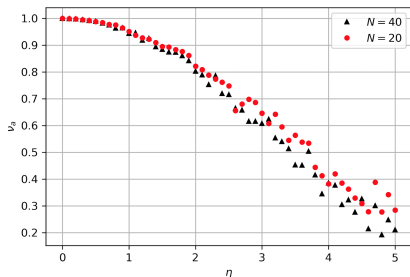


Figure: ν_a vs η

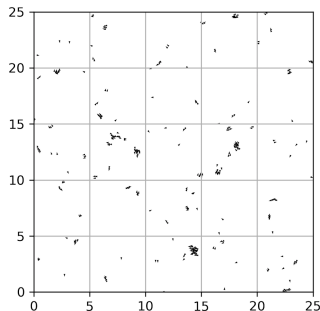


Figure: Clustering of particles after 500 runs under low noise and low density.



Any questions?

Project hosted at:

- Extended Craig Reynolds Model:
<https://chahak13.github.io/fish-boids>
- Vicsek Model: <https://97amarnathk.github.io/VicsekModel>

References:

- Reynolds, Craig W. "Flocks, Herds, and Schools: A Distributed Behavioral Model". In: *SIGGRAPH Computer Graphics* 21.4 (1987), pp. 25–34. ISSN: 0097-8930. URL: <http://doi.acm.org/10.1145/37402.37406>.
- Vicsek, Tamás et al. "Novel Type of Phase Transition in a System of Self-Driven Particles". In: *Phys. Rev. Lett.* 75.6 (1995), pp. 1226–1229. DOI: [10.1103/PhysRevLett.75.1226](https://doi.org/10.1103/PhysRevLett.75.1226).

