SYNC or Swim

A Particle Model of the Interaction within Fish Schools

David Ebert and Mikaela Jordan

Tarleton State University

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Synchronization

The coordination of events to operate a system in unison.
Some examples:

- Circadian Rhythms

Synchronization

The coordination of events to operate a system in unison.
Some examples:

- Animal Swarming

Synchronization

The coordination of events to operate a system in unison.

Some examples:

- Human Imitation (Memes/Trends)

Synchronization

The coordination of events to operate a system in unison.
Some examples:

- Round of Applause

Example - Human Grouping

Rules to Follow:

- **Walk** slowly toward center of the group.
- **Slow down** if you're within two feet of another person.
- **Stop** if you are within one foot of another person.

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Collective Behavior

- The coordinated behavior of animals of the same species and the emergent properties that arise.

Collective Behavior

- The coordinated behavior of animals of the same species and the emergent properties that arise.
- For mathematical purposes, consider a swarm as an emergent behavior with no central coordination.

Why Do We Care?

- Learning C/CUDA
- Applying mathematical models to real life phenomenon
- How will environmental factors affect the animal aggregate
- How animal aggregates will affect the environment

Flocking Model

Our model represents each fish adhering to the following three rules:

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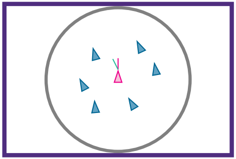
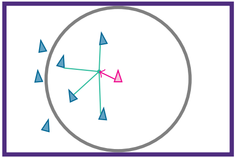


- **Alignment**

Flocking Model

Our model represents each fish adhering to the following three rules:

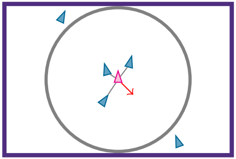
- **Alignment**
- **Cohesion**



Flocking Model

Our model represents each fish adhering to the following three rules:

- **Alignment**
- **Cohesion**
- **Separation**



The Mathematics

- Lagrangian Algorithm

- Metric distance model

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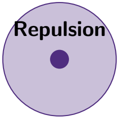
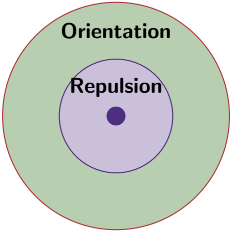
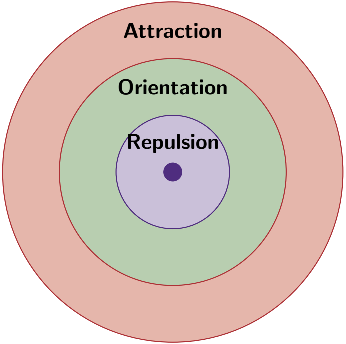


- Metric distance model



- Metric distance model



Attractive and Repulsive Forces Between Fish

- Attraction between a fish i and neighbor j :

$$A = C_a \frac{p_j - p_i}{d^2}$$

Attractive and Repulsive Forces Between Fish

$$A = C_a \frac{p_j - p_i}{d^2}$$

- Repulsion between fish i and neighbor j:

$$R = -C_r \frac{p_j - p_i}{d^4}$$

Attractive and Repulsive Forces Between Fish

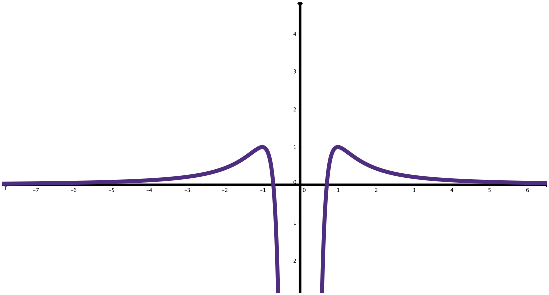
$$A = C_a \frac{p_j - p_i}{d^2}$$

$$R = -C_r \frac{p_j - p_i}{d^4}$$

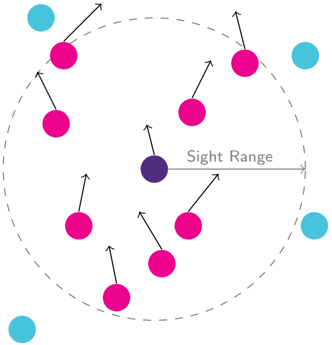
- Overall Attraction:

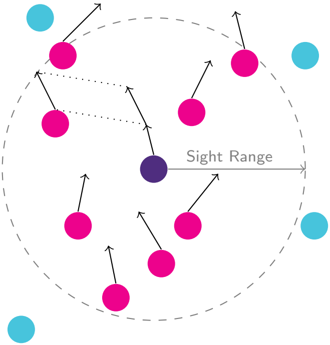
$$F_A = C_a \frac{p_j - p_i}{d^2} - C_r \frac{p_j - p_i}{d^4}$$

$$f(x) = \frac{2}{x^2} - \frac{1}{x^4}$$

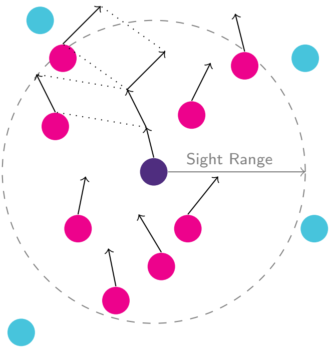


Directional Alignment of Fish i




Sight Range

Directional Alignment of Fish i



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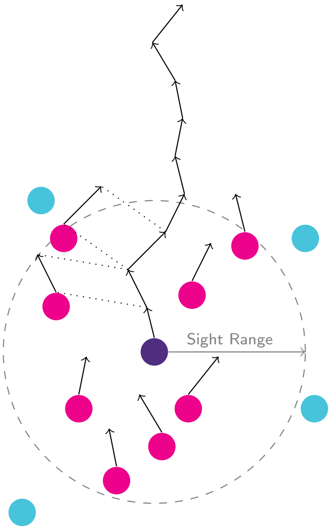

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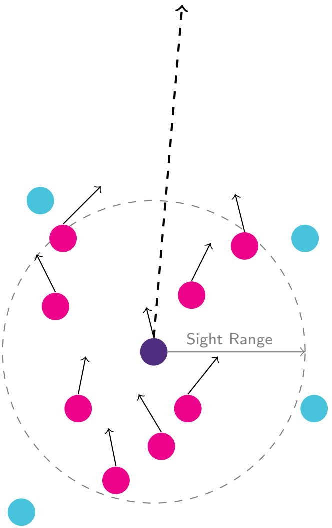

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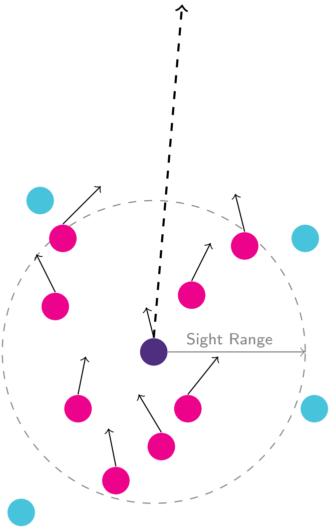

$$F_{D_i} = \sum_{j=1}^{N} \frac{v_j}{||p_i - p_j||}$$

Total Force on Fish i From All Neighbors

$$F_{i_N} = \sum_{j=1}^{N} \left(W_a \left(C_a \frac{p_j - p_i}{d^2} - C_r \frac{p_j - p_i}{d^4} \right) + W_d \left(\frac{v_j}{||p_i - p_j||} \right) \right) \quad (1)$$

Total Force on Fish i From All Neighbors

$$F_{i_N} = \sum_{j=1}^{N} \left(W_a \left(C_a \frac{p_j - p_i}{d^2} - C_r \frac{p_j - p_i}{d^4} \right) + W_d \left(\frac{v_j}{||p_i - p_j||} \right) \right) \quad (1)$$

And, acceleration of each fish is the same as our force (taking each mass to be 1).

Calculating Forces, Velocities, and Positions

At every timestep, the following calculations occur for each particle (let's call it particle i):

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Calculating Forces, Velocities, and Positions

At every timestep, the following calculations occur for each particle (let's call it particle i):

1. Calculate $||p_i - p_j||$.

Calculating Forces, Velocities, and Positions

At every timestep, the following calculations occur for each particle (let's call it particle i):

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2. If the $||p_i - p_j|| <$ SIGHT, use (1) to determine the force between particle j and particle i, and sum forces over all particles within SIGHT of particle i (F_{i_N}).

Calculating Forces, Velocities, and Positions

At every timestep, the following calculations occur for each particle (let's call it particle i):

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3. Use F_{i_N} calculated above to update particle i's velocity as follows:

$$v_i = v_i + F_{i_N} \cdot dt$$

Calculating Forces, Velocities, and Positions

At every timestep, the following calculations occur for each particle (let's call it particle i):

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4. And update particle i's position using:

$$p_i = p_i + v_i \cdot dt$$

Simulations

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Where Do We Go From Here?

- Add initial conditions for species-specific parameters
  - Density of swarms, how they behave towards targets and obstacles, etc.
- Move calculations from CPU to GPU to speed up calculation time

References

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THANK YOU

Thank you to Dr. Wyatt and the Particle Modelling Lab for their time and resources.

QUESTIONS?