SYNC or Swim

A Particle Model of the Interaction within Fish Schools

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Synchronization

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

- Circadian Rhythms
- Round of Applause (WHAT?!?! - Let's try it!)

Example - Human Grouping

Coupling

One object influencing another by providing feedback.
Real life examples

- Animal Swarming

Coupling

One object influencing another by providing feedback.
Real life examples

- Human Imitation (Memes/Trends)

Collective Behavior

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

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- For mathematical purposes, consider a swarm as an emergent behavior with no central coordination that arises due to several simple instinctual rule that animals of a given species follow.
- Other terms we will be using interchangeably with "collective behavior": swarm, school(specific to fish), aggregate

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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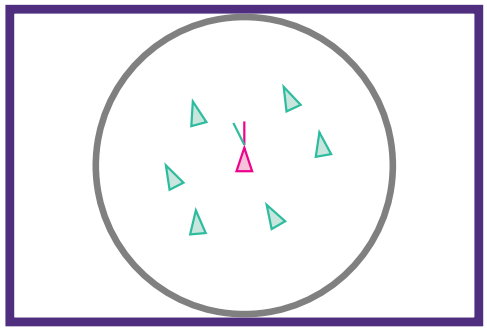
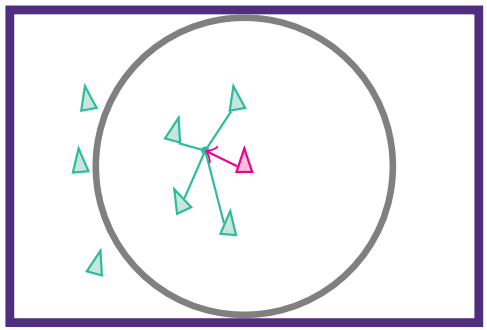


- **Alignment**

Flocking Model

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

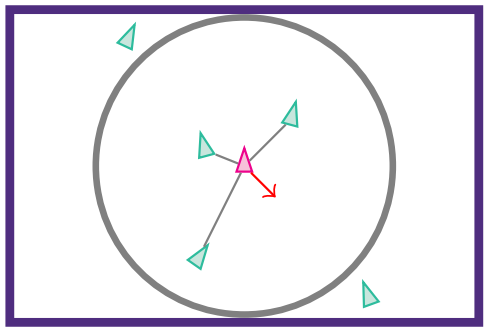
- **Alignment**
- **Cohesion**



Flocking Model

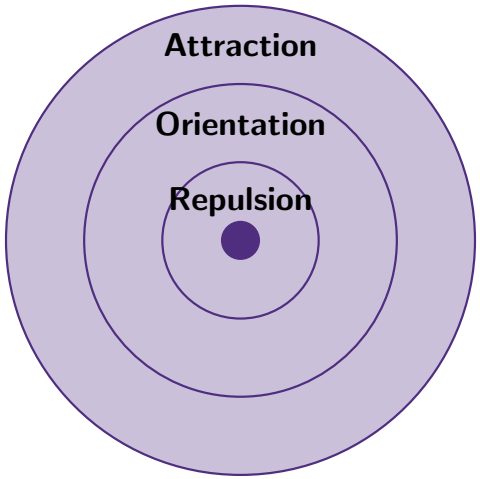
Our model represents each fish adhering to the following three rules:

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



The Mathematics

- Lagrangian Algorithm
- Metric distance model



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

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- Repulsion between fish i and neighbor j:

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

Attractive and Repulsive Forces Between Fish

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

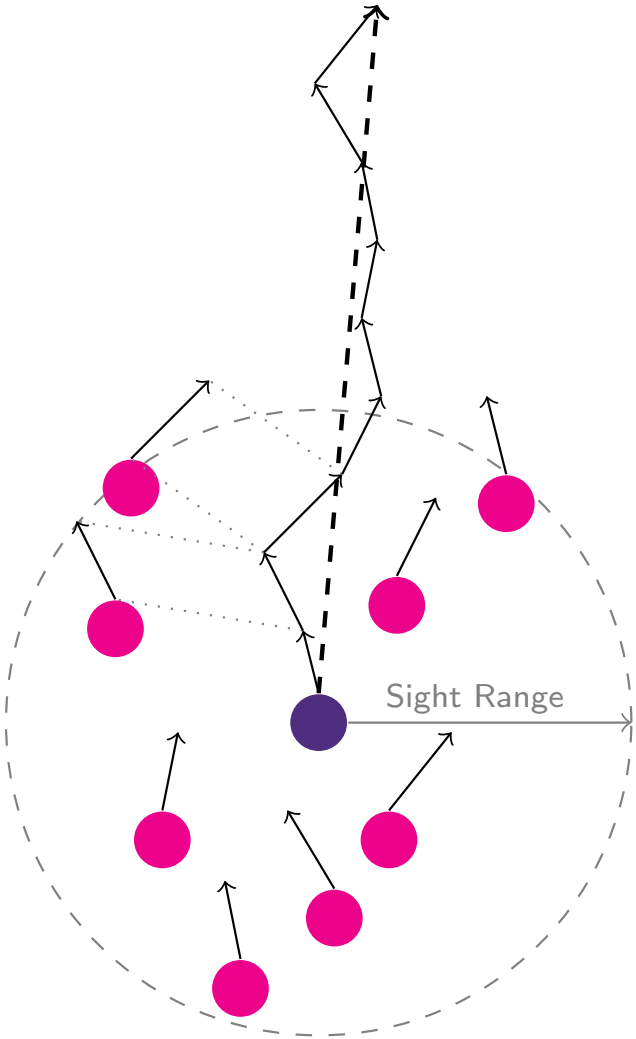
$$R = -C_r \frac{p_j - p_i}{d^4}$$

- Overall Attraction:

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

The Attraction and Repulsion Coefficients

Directional Alignment of Fish i



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

Total Force on Fish i From All Neighbors

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

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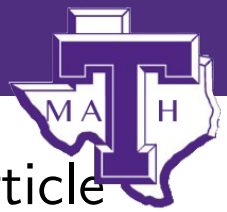
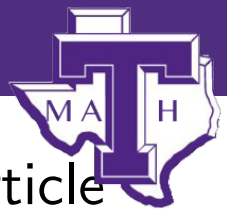
And, acceleration of each fish is the same as our force (taking each mass to be 1).

Calculating Forces, Velocities, and Positions



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

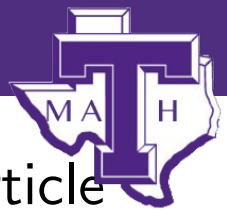
Calculating Forces, Velocities, and Positions



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

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

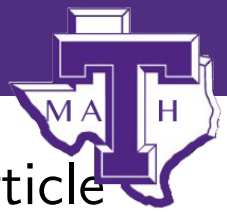
Calculating Forces, Velocities, and Positions



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

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):

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

$$v_i = v_i + a_i \cdot dt$$

Calculating Forces, Velocities, and Positions

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

4. And update particle i's position using:

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

Simulations

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

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QUESTIONS?