Flocking, Herding and Schooling

CS 790R

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Overview

- Description of the behavior
- Overview of the Reynolds Model (1987)
- Overview of the Huth & Wissel Model (1992)
- Extension of the Huth & Wissel Model
- Demo

Behavior

- Polarized, noncolliding aggregate motion of a group of animals
- The group is formed and moves without an apparent leader yet with an impression of intentional, centralized control
- The group moves and reacts to its environment collectively (i.e. predators, obstacles)

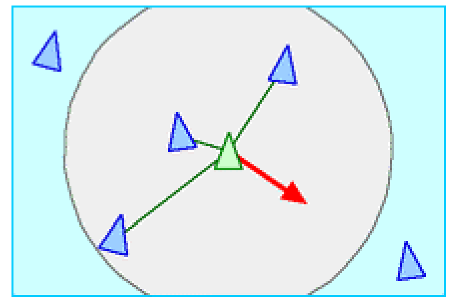
Reynold’s Boids

- "Boid" was an abbreviation of "birdoid", as his rules applied equally to simulated flocking birds, and schooling fish
- Approach to computer simulation of flocking/herding/schooling behavior
- Implementation of a “control structure” for each individual – in other words, rules for each agent

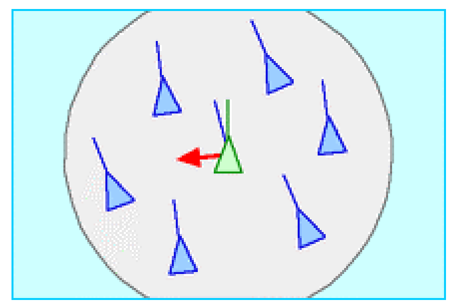
http://www.red3d.com/cwr/boids/

Behaviors

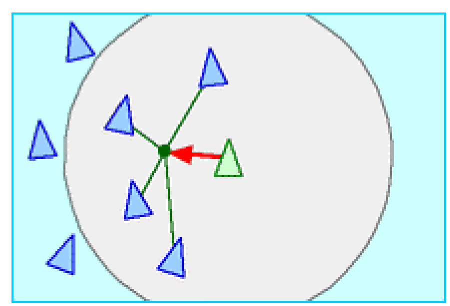
- Collision Avoidance
- Velocity Matching
- Flock Centering
- Steering



Separation: steer to avoid crowding local flockmates



Alignment: steer towards the average heading of local flockmates



Cohesion: steer to move toward the average position of local flockmates

Source: http://www.red3d.com/cwr/boids/

Parameters Modeled

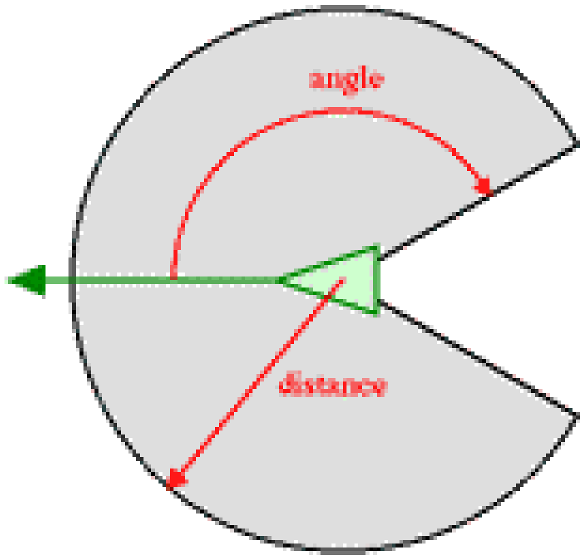
- Geometric Flight – defined as a certain type of motion along a path: a dynamic, incremental, rigid geometrical transformation of an object, moving along and tangent to a 3D curve
- Gravity is applied solely for banking behavior

Parameters continued

- Incremental geometric flight is a discrete approximation of real flight
- Uses the birds own coordinate system, in Cartesian terms, the left/right axis is X, up/down is Y, and forward/back is Z
- Local scale: unit of length is defined as one body length
- Maximum speed is defined through a simple model of viscous speed dampening
- Maximum acceleration is expressed as a fraction of the maximum speed
- Enables the model to exhibit behavior of a creature with a finite amount of available energy

Sensor Model

- Local neighborhood defined by sensory boundaries
- When the model allowed each individual to have complete knowledge of the entire flock, it didn’t behave as expected
- Therefore, the neighbors are what influences each individual



Source: http://www.red3d.com/cwr/boids/

Computer Animation: Flocking

- Susan Amkraut developed Flock, a system using vector force fields to control the motion of a flock of birds
- A vector force field can be seen as a space in which each point in space is assigned a directed arrow or “vector”
- A moving organism (agent) can be “given directions” about where it should move to at every point it passes through. (rules)
- All the paths taken together, constitute the flow of the vector field
- The fields produce flows from linear differential equations, which can be elegantly classified by their “shapes of movement” in space
- The classes include flows that repel, attract, and spin organisms about different axes in their own coordinate system.

- http://www.siggraph.org/artdesign/profile/csuri/research/eurythmy.html

Reference: Csuri, CA IEEE Computer Graphics and Applications v11, n1, pp. 30-35 1991

Computer Animation: Herding

- Disney created a system that used principles from Reynold's boid model to create the stampede of wildebeests in the movie Lion King
- The main difference is that they did define leaders and followers
- They started with a 2D representation and then used CGI to create a 3D environment
- From production notes: We were also able to individualize and vary the movement of each animal within a group to give them a certain random quality. Effectively they could all be doing different things with the library of behavior including slow and fast gallops, various head tosses and even a few different kinds of leaps

Play Movie

Huth & Wissel Model

- Assumptions in the Huth and Wissel model
  - Every fish swims within the school according to the same behavioral model. This guarantees that the model fish group moves without a leader.
  - The motion of the model fish group is not affected by external influences (no destination).
  - Random influences are taken into account for the individual fish. Therefore, the position and the velocity of each fish were constructed as stochastic variables.
  - The motion of each fish is only influenced by its nearest neighbors. This takes into account that vision and lateral line are considered to be most important senses for school organization.
  - We attempted to construct simple models possible. Only simple models promote a comprehension of the results. In other words, we are not interested in modeling every detail of the fish behavior, but only the behaviors which are decisive for the school organization.

Features

- Parallel orientation
- Repulsion
- Biosocial Attraction
- Searching

Parallel Orientation

- A schooling fish prefers to have its neighbors in distinct ranges
- The range varies by species (0.3 to 3 body lengths (BL))
- To maintain parallel orientation and preferred spacing, the following properties are necessary:
  - Repulsion
  - Attraction
  - Searching

Repulsion

- Collision avoidance
- Rule: if the neighbor fish is too close, the fish tries to avoid a collision by turning a calculated angle

Biosocial Attraction

- Fish tend to want to be near fish of the same species. If a fish is to far away from the school, it swims toward the school.

- Rule: if the neighboring fish is too far away (in the attraction area), the fish swims in the direction of its neighbor

Searching

- When a fish is separated from the school, all neighbors are outside of the sensory area of the fish, the search behavior is invoked

- Rule: if the neighbor fish is too far away or in the dead angle of the fish, the fish begins to search for a neighbor fish.

Conceptual Behavior Models

- Decision (D-model)
  - The fish decide to which neighbor is will adjust
- Averaging (A-model)
  - The fish mixes the influences of its neighbors

Results

- In standard runs there were 8 fish simulated through 100 timesteps in 2D starting from a random initial configuration
- The A-model did represent the schooling behavior while the D-model resulted in a permanent confusion

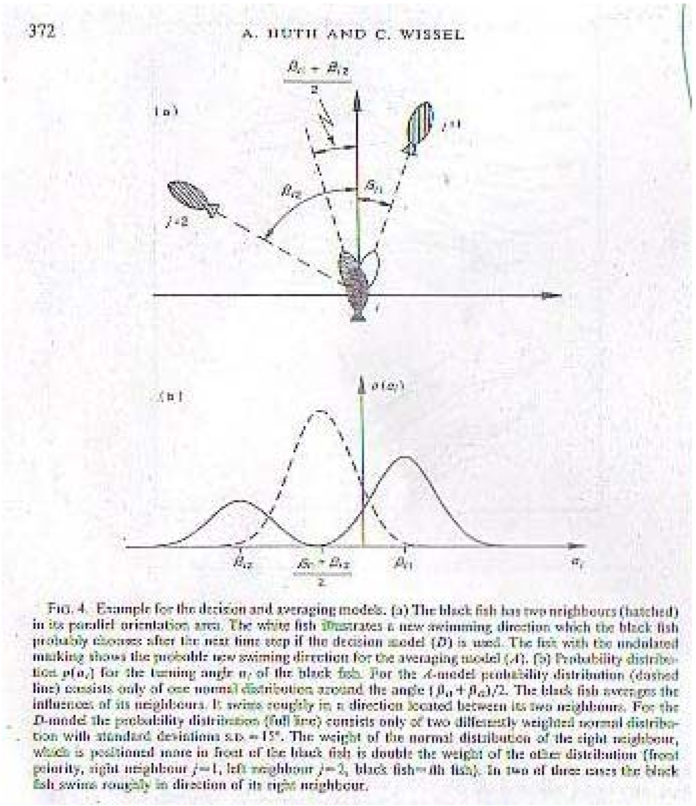

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FIG. 4. Example for the decision and averaging models. (a) The black fish has two neighbours (hatched) in its parallel orientation area. The white fish illustrates a new swimming direction which the black fish probably chooses after the next time step if the decision model (D) is used. The fish with the undulated marking shows the probable new swiming direction for the averaging model (A). (b) Probability distribution $p(\alpha_i)$ for the turning angle α_i of the black fish. For the A-model probability distribution (dashed line) consists only of one normal distribution around the angle $(\beta_{i1}+\beta_{i2})/2$. The black fish averages the influences of its neighbours. It swims roughly in a direction located between its two neighbours. For the D-model the probability distribution (full line) consists only of two differently weighted normal distribution with standard deviations s.d. = 15°. The weight of the normal distribution of the right neighbour, which is positioned more in front of the black fish is double the weight of the other distribution (front priority, right neighbour $j=1$, left neighbour $j=2$, black fish = ith fish). In two of three cases the black fish swims roughly in direction of its right neighbour.

Adding External Influences

- Extension of the Huth & Wissel model to include predation was discussed in Self-Organization in Biological Systems Chapter 11: Fish Schooling
- They hypothesize that schooling is a phenomena that developed as a survival mechanism
- Also, as a way to allow for the group to aid in the speed and energy requirements for migration – endurance of fish can be increased as much as six times when traveling in a school
- Also, suggested that one property is the rapid transmission of information between individuals is a benefit of the flock – Trafalgar Effect
- Also evasive maneuvers occur within the school as if directed
- This can also aid in gathering prey by the behaviors induced by schooling

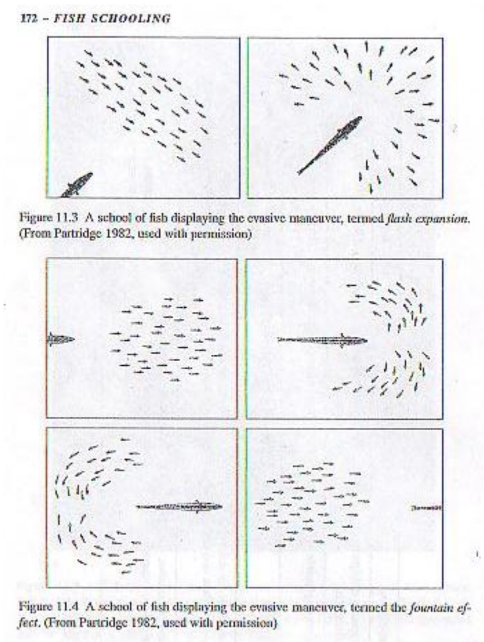
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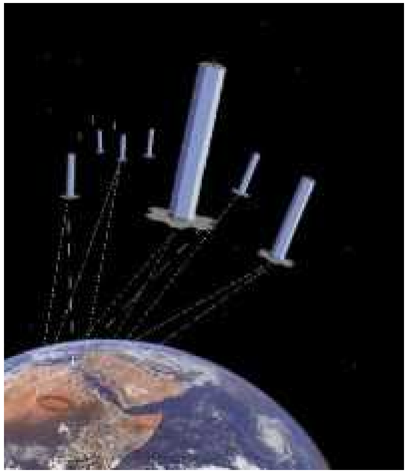
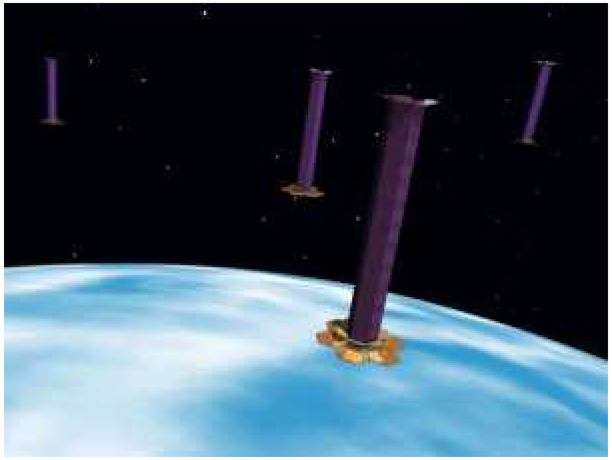
Figure 11.3 A school of fish displaying the evasive maneuver, termed *flash expansion*. (From Partridge 1982, used with permission)

Figure 11.4 A school of fish displaying the evasive maneuver, termed the *fountain effect*. (From Partridge 1982, used with permission)

Applications

- Satellite clusters
- Each smaller satellite communicates with the others and shares the processing, communications, and payload or mission functions. Thus, the cluster of satellites forms a “virtual satellite”





http://www.vs.afrl.af.mil/TechProgs/TechSat21/

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The Simulation of the Movement of Fish Schools

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Camazine, S., Deneubourg, J.-L., Franks, N. R., Sneyd, J., Theraulaz, G. and Bonabeau, E.