Read Ch. 17: Cooperation & Competition

Schools, Flocks, & Herds
“and the thousands of fishes moved as a huge beast, piercing the water. They appeared united, inexorably bound to a common fate. How comes this unity?”
— anon., 17th cent.

Coordinated Collective Movement
- Groups of animals can behave almost like a single organism
- Can execute swift maneuvers – for predation or to avoid predation
- Individuals rarely collide, even in frenzy of attack or escape
- Shape is characteristic of species, but flexible

Adaptive Significance
- Prey avoiding predation
- More efficient predation by predators
- Other efficiencies
Avoiding Predation

- More compact aggregation
  - predator risks injury by attacking
- Confusing predator by:
  - united erratic maneuvers (e.g. zigzagging)
  - separation into subgroups (e.g., flash expansion & fountain effect)
Fountain Effect

Fig. from Camazine & al., Self-Org. Biol. Sys.

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Better Predation

- Coordinated movements to trap prey
  - e.g., parabolic formation of tuna
- More efficient predation
  - e.g., killer whales encircle dolphins
  - take turns eating
Other Efficiencies

- Fish schooling may increase hydrodynamic efficiency
  - endurance may be increased up to 6x
  - school acts like “group-level vehicle”
- V-formation increases efficiency of geese
  - range 70% greater than that of individual
- Lobsters line up single file by touch
  - move 40% faster than when isolated
  - decreased hydrodynamic drag

Characteristic Arrangement of School

- Shape is characteristic of species
- Fish have preferred distance, elevation & bearing relative to neighbors
- Fish avoid coming within a certain minimum distance
  - closer in larger schools
  - closer in faster moving schools

Alternatives to Self-Organization

- “Templates”
  - no evidence that water currents, light, chemicals guide collective movement
- “Leaders”
  - no evidence for leaders
  - those in front may drop behind
  - those on flank may find selves in front
  - each adjusts to several neighbors
- “Blueprint” or “Recipe”
  - implausible for coordination of large schools
  - e.g., millions of herring, hundreds of millions of cod

Self-Organization Hypothesis

- Simple attraction & repulsion rules generate schooling behavior
  - positive feedback: brings individuals together
  - negative feedback: but not too close
- Rules rely on local information
  - i.e. positions & headings of a few nearby fish
  - no global plan or centralized leader
Mechanisms of Individual Coordination

- Vision
  - governs attraction
  - & alignment
- Lateral line
  - sensitive to water movement
  - provides information on speed & direction of neighbors
  - governs repulsion
  - & speed matching
- How is this information integrated into a behavioral plan?
  - most sensitive to nearest neighbors

Basic Assumptions of Huth & Wissel (1992) Model

- All fish follow same rules
- Each uses some sort of weighted average of positions & orientations of nearest neighbors
- Fish respond to neighbors probabilistically
  - imperfect information gathering
  - imperfect execution of actions
- No external influences affect fish
  - e.g. no water currents, obstacles, …

Ranges of Behavior Patterns

Fig. adapted from Camazine & al., Self-Org. Biol. Sys.

Model Behavior of Individual

1. Determine a target direction from each of three nearest neighbors:
   - if in repel range, then 180° + direction to neighbor
   - else if in orient range, then heading of neighbor
   - else if in attract range, then accelerate if ahead, decelerate if behind;
     return direction to neighbor
   - else return our own current heading
2. Determine overall target direc. as average of 3 neighbors inversely weighted by their distances
3. Turn a fraction in this direction (determined by flexibility) + some randomness
Demonstration of Simulation of Flocking/Schooling

Run Flock.slogo

Limitations of Model

- Model addresses only motion in absence of external influences
- Ignores obstacle avoidance
- Ignores avoidance behaviors such as:
  - flash expansion
  - fountain effect
- Recent work (1997-2000) has addressed some of these issues

“Boids”

A model of flocks, herds, and similar cases of coordinated animal motion by Craig Reynolds (1986)

Boid Neighborhood
Steering Behaviors

- Separation
- Alignment
- Cohesion

Separation
Steer to avoid crowding local flockmates

Alignment
Steer towards average heading of local flockmates

Cohesion
Steer to move toward average position of local flockmates
**Velocity Vector Update**

- Compute $v_{\text{separate}}$, $v_{\text{align}}$, $v_{\text{cohere}}$ as averages over neighbors
- Let $v_{\text{change}} =$
  
  $w_{\text{separate}} v_{\text{separate}} + w_{\text{align}} v_{\text{align}} + w_{\text{cohere}} v_{\text{cohere}}$

- Let $v_{\text{new}} = \mu v_{\text{old}} + (1 - \mu) v_{\text{change}}$

**Obstacle Avoidance**

- Boid flock avoiding cylindrical obstacles (Reynolds 1986)
- This model incorporates:
  - predictive obstacle avoidance
  - goal seeking (scripted path)

**Demonstration of boids**

Run Craig Reynolds’s boids at [http://www.red3d.com/cwr/boids](http://www.red3d.com/cwr/boids)

**Use in Computer Animation**

Extract from Stanley and Stella in “Breaking the Ice” (1987)

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