Lecture 18

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

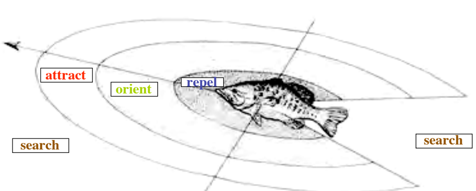


Fig. adapted from Camazine & al., *Self-Org. Biol. Sys.*

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 NetLogo Simulation of Flocking/Schooling

based on Huth & Wissel Model

Run Flock.nlogo

10/25/07 7

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 (since 1997) has addressed some of these issues

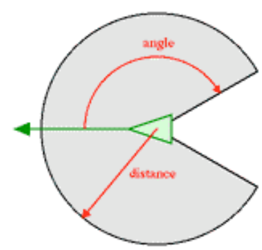
10/25/07 8

"Boids"

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

10/25/07 9

Boid Neighborhood



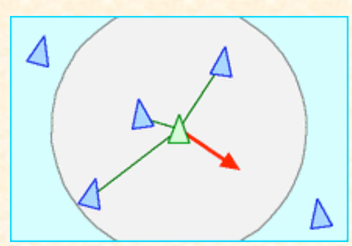
10/25/07 10

Steering Behaviors

- Separation
- Alignment
- Cohesion

10/25/07 11

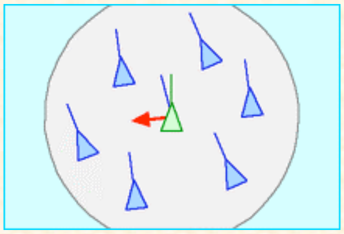
Separation



Steer to avoid crowding local flockmates

10/25/07 Fig. from Craig Reynolds 12

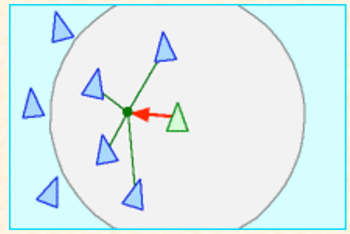
Alignment



Steer towards average heading of local flockmates

10/25/07 Fig. from Craig Reynolds 13

Cohesion



Steer to move toward average position of local flockmates

10/25/07 Fig. from Craig Reynolds 14

Velocity Vector Update

- Compute $\mathbf{v}_{separate}$, $\mathbf{v}_{align}$, $\mathbf{v}_{cohere}$ as averages over neighbors
- Let $\mathbf{v}_{change}$ =
  $w_{separate}\ \mathbf{v}_{separate}$
  $+\ w_{align}\ \mathbf{v}_{align}$
  $+\ w_{cohere}\ \mathbf{v}_{cohere}$
- Let $\mathbf{v}_{new} = \mu\ \mathbf{v}_{old} + (1 - \mu)\ \mathbf{v}_{change}$

momentum factor

10/25/07 15

NetLogo Simulation

- Flockmates are those within "vision"
- If nearest flockmate < minimum separation, turn away
- Else:
  - align with average heading of flockmates
  - cohere by turning toward average flockmate direction
- All turns limited specified maxima
- Note fluid behavior from deterministic rules

10/25/07 16

Demonstration of boids

Run Flocking.nlogo

10/25/07 17

Demonstration of boids (with 3D perspective)

Run Flocking (Perspective Demo).nlogo

10/25/07 18

Demonstration of 3D boids

Run Flocking 3D.nlogo

10/25/07 19

Obstacle Avoidance

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

10/25/07 20

Jon Klein's Flocking Algorithm

- Sight limited by "vision"
- Balances 6 "urges":
  - be near center of flock
  - have same velocity as flockmates
  - keep spacing correct
  - avoid collisions with obstacles
  - be near center of world
  - wander throughout world
- Strength of urge affects acceleration

10/25/07 21

Demonstration of Klein's Flocking Algorithm

Run Flocking 3D Alternate.nlogo

10/25/07 22

Use in Computer Animation

- Extract from *Stanley and Stella in "Breaking the Ice"* (1987)
- store.yahoo.com/odyssey3d/comanclascli2.html

10/25/07 23

Particle Swarm Optimization

(Kennedy & Eberhart, 1995)

10/25/07 24

Motivation

- Originally a model of social information sharing
- Abstract vs. concrete spaces
  - cannot occupy same locations in concrete space
  - can in abstract space (two individuals can have same idea)
- Global optimum (& perhaps many suboptima)
- Combines:
  - private knowledge (best solution each has found)
  - public knowledge (best solution entire group has found)

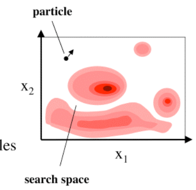
Particle Swarms

Idea

- moving points in the search space, which refine their knowledge by interaction

What is a particle?

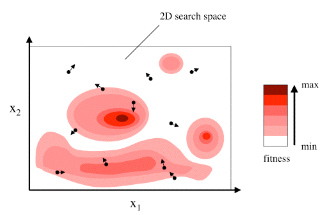
- a particle consists of:
  - $\vec{x}_i$ position
  - $\vec{v}_i$ velocity
  - $\vec{p}_i$ best position found so far
  - velocity and position update rules



(Kennedy and Eberhart, 1995)

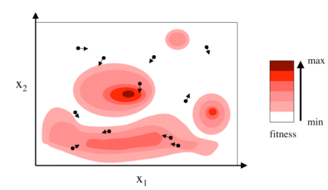
Example

Particle Swarms



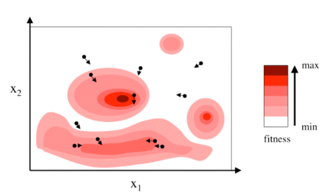
Example

Particle Swarms



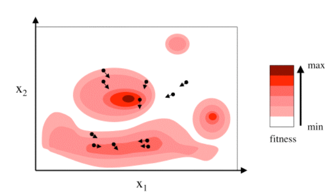
Example

Particle Swarms



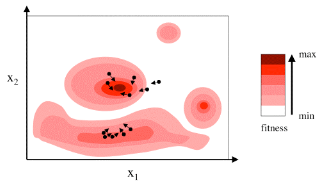
Example

Particle Swarms



Example

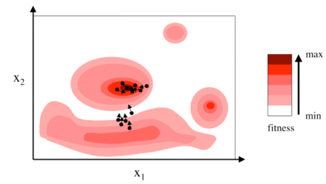
Particle Swarms



10/25/07 Fig. from EVALife site 31

Example

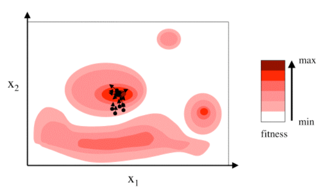
Particle Swarms



10/25/07 Fig. from EVALife site 32

Example

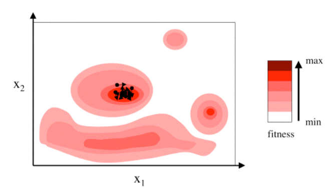
Particle Swarms



10/25/07 Fig. from EVALife site 33

Example

Particle Swarms



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