ALARM PRACTICE 2

System Analysis Course
Prepared by Dr. Oleksii Ignatenko

OBJECTIVES

Learn about flocking models

Try in practice established models and evaluate their properties

Use Netlogo to perform simulation and build predators - birds model

Create a report with measured metrics and findings

WHAT TO DO

1. Follow this document. Read the model description and create an appropriate Netlogo model.
2. Read chapters in books with additional information
3. Do exercises and fill your report document with the images and plots required.

FLOCKING MODELS

Models of flocking behavior explore the conditions of imitation, attraction, and repulsion between individual entities, under which spontaneous concerted movement of large groups, in other words, flocking, can emerge and be sustained. The most frequently cited original source for simulation models of this type is a conference paper by Craig Reynolds (1987), which presents the basic features of a model that allows the graphical simulation of flocking behavior.

Individuals in Reynolds's flock observe three basic rules. First, they avoid colliding with other individuals, essentially by not getting too close to one another, a repulsion effect. Second, they try to match their speed and direction of movement to their near neighbors, an imitation or alignment effect. Finally, individuals aim to remain in the flock by staying within range of near neighbors, an attraction effect. The motivation behind Reynolds's model was the simulation of flocking behavior for special effects in films and computer games. His model has formed the basis for developments in that field over recent decades. Reynolds model is implemented in the standard Netlogo library as flocking.

A more formally presented academic model, even simpler than Reynolds's, is described by Vicsek et al. (1995). This model assumes that all individuals are moving at the same speed v and that they adjust their direction of movement or heading θ to the mean heading of nearby individuals within some range r, with the addition of a noise factor:

$$\theta(t+1)= \theta(t)\ r + c\_\theta$$

where c_θ is a uniformly distributed random angle in some range [−η, +η]. All individuals adjust their heading according to this equation each time step before moving a distance v in this new direction. If the speed v is considered a fraction of the neighborhood range r and we set r = 1, then this model has only three free parameters: v, η, and the density ρ of individuals per unit area.

Elaborating this model rapidly becomes rather complex and demands some care in how the neighboring individuals (or flockmates), which affect the alignment and relative movement of individuals, are determined.

Laboratory work 3.

This laboratory work consists of two parts. The first part is to implement the Vicsek model and measure metrics for different v, η, and fixed numbers of agents. The second is to add extensions and simulate.

Metrics to consider:

1. To monitor the global alignment of the system as time evolves, we define the global alignment coefficient.

$$\psi_n = \frac{1}{N} \left| \sum_{j=1}^{N} \frac{\mathbf{v}_{j,n}}{v} \right|$$

2. Given a particle i, let Ai,n be the area of the Voronoi polygon for particle i at iteration n. We define the global clustering coefficient as:

$$c_n = \frac{\text{count}\left\{ A_{i,n} < \pi\ R_{\mathrm{f}}^{2} \right\}}{N},$$

3. Alignment

   Let's pick a metric for alignment: polarization is the average angular deviation from the average direction of the flock. A flock is fully aligned when the polarization is 0 degrees and least aligned at 90 degrees.

4. Implement another clustering metric called the Number of flocks. Let us define the new variable min-flock-distance. Use the idea of percolation clusters we used in the lecture to define flocks for each bird. The number of flocks and mean size are important measures.

Variants.

0. Implement Vicsek for 100 agents in a 50x50 world. Measure metrics 1 - 2 for different v, η and perform analysis of behavior - basically find types of movements and value regions.

Add leaders, which brings more attraction from other birds. Calculate metrics and measure dependency on a number of leaders.

1. Take the Vicsek model for 500 agents in a 50x50 world. Measure metrics 3 - 4 for different v, η and perform analysis of behavior - basically find types of movements and value regions.

Add families, N types of birds, that have more attraction to each other (each bird is more inclined to be near its own family).

2. Take the Vicsek model for 300 agents in a 50x50 world. Measure metrics 1 - 2 for different v, η and perform analysis of behavior - basically find types of movements and value regions. Add obstacles; now birds should detect walls and avoid them if possible and measure metrics for the long tunnel with M birds flying through, show emergent effects when a number of birds grow.

3. Take the Vicsek model as a start. Add predators and show how time-to-kill depends on the velocity and number of predators. The logic of predators - seek the closest bird and attack it. The velocity of predators is higher than of birds. When a predator is in the

range of sight, birds should fly to avoid the predator (think about realistic logic - the goal is to propose your own set of rules).

Sources

1. Simulation of Complex Systems Aykut Argun, Agnese Callegari and Giovanni Volpe. Chapter 8 The Vicsek model.