Flocking - Obstacles

Description:

It is commonly observed that birds, fish, insects, and other animals form flocks or swarms. It is believed that one mechanism that drives this effect is that each animal observes the velocity of those nearby and aligns its own velocity to the local average. Animals also try to stay close to a group, and also avoid bumping in to each other and objects. Wolverhampton Windfarms install turbines and other structures related to green energy. They are interested in how these structure can affect the flocking of birds. Ideally, they would like to minimise this, perhaps based on the profile of the structure, or grid pattern for multiple turbines. They have seen some results of simple models and are interested in understanding if and how they can be applied in more realistic situations. In particular, they are hoping to determine how such models work when birds interact with multiple objects in their environment. They are also potentially interested in what the model can tell them about the effects of wind on the motion of birds.

Aims:

Wolverhampton Windfarms wish to understand some/all of the following:

- Can the model treat obstacles in the environment?
- If so, what does it tell us about the effects of these obstacles on the formation of flocks?
- What are the effects of changing the number and placement of the objects? Is there an 'optimal' way to introduce a number of structures to minimise the disruption of flocks.
- Can wind be incorporated in the model? What effect does it have?
- Is there any real-world data that the model can be benchmarked against? In particular, is it possible to determine reasonable values for any of the parameters?

An initial model:

Environment:

A two-dimensional domain. [You could begin with periodic boundary conditions, but may want to modify this later in the Project.]

Agents:

A number, N, of birds, each with a position x_i and velocity v_i.

Algorithm:

The motivation for the model is that birds can only observe other birds within a certain range. They then try to (i) move towards the centre of nearby flocks; (ii) avoid colliding with other birds; (iii) match their velocity with nearby birds. Birds are restricted to a maximum velocity.

Define a maximum velocity $v_{\max}$, 'mixing' parameters λ_c, λ_a, and λ_m, a distance over which birds can observe their neighbours, R, and a minimum distance they would like to maintain, r. For each bird, define neighbours that they can see, $\mathcal{N}_i = \{j : \|x_i - x_j\| < R\}$, and that are too close $\mathcal{A}_i = \{j : \|x_i - x_j\| < d\}$.

For an arbitrary state, one update of the system consists of the following steps, performed in parallel for all birds:

1. **Centre of mass:** determine the velocity towards the centre of mass of local birds:

$$v_i^c = \lambda_c \Big(\frac{\sum_{j \in \mathcal{N}_i} x_j}{\#\mathcal{N}_i} - x_i \Big),$$

   where $\#\mathcal{N}_i$ is the number of elements of $\mathcal{N}_i$

2. **Avoid collisions:** determine the velocity away from potential collisions:

$$v_i^a = \lambda_a \sum_{j \in \mathcal{A}_i} (x_i - x_j).$$

3. **Match velocities:** determine how to align to local velocities:

$$v_i^m = \lambda_m \Big(\frac{\sum_{j \in \mathcal{N}_i} v_j}{\#\mathcal{N}_i} - v_i \Big).$$

4. **Update velocities:**

$$v_i(t+1) = v_i(t) + v_i^c + v_i^a + v_i^m.$$

5. **Limit speed:**

$$v_i(t+1) = \min\left(1, \frac{v_{\max}}{\|v_i\|}\right) v_i(t+1).$$

Reference:

'Flocks, Herds, and Schools: A Distributed Behavioral Model', Craig W. Reynolds, Computer Graphics, **21**(4), 25–34, 1987, `http://www.cs.toronto.edu/~dt/siggraph97-course/cwr87/`

[Note that this paper doesn't contain explicit choices for the interactions; I've chosen one of the standard ones. You should feel free to modify these choices.]