CSCI 4314/5314 Dynamic Models in Biology
Homework Set 3

Simulation of Flocks (50 points)

This homework will illustrate swarm intelligence through a flocking example. As discussed in the lecture, you can achieve coherent emergent behavior (flocking) of a swarm, when each agent is 1) attracted to other agents, 2) repulsed when too close to other agents, and 3) performing velocity alignment with other agents. In other words, the behavior is not something we program directly, instead it is an emergent property of many locally interacting individuals. We will examine this behavior in 2D; the swarm will be composed of N agents; each agent will be defined by its position (p) and velocity (v).

First, generate a randomized initial distribution of agents, with a Gaussian spread about the origin and a Gaussian spread of velocities. The size of the spread is determined by P and V:

```
p = P*randn(2,N);
v = V*randn(2,N);
```

Second, create the loop that iterates the motion of the flock. In real life each agent would update asynchronously, but for simplicity we use synchronized agents here. For each iteration of the loop, position and velocity must be updated according to the laws of attraction, repulsion, and velocity alignment. We will compute the distance and velocity mismatch between agents, m and n, and update accordingly:

```
r = p(:,m)-p(:,n); %Vector from agent n to m
rmag = sqrt(r(1)^2+r(2)^2); %Distance between agents n and m
v1(:,n) = v1(:,n) + c1*r; %Attraction
v2(:,n) = v2(:,n) - c2*r/(rmag^2); %Repulsion (non-linear scaling)
v3 = [sum(v(1,:))/N; sum(v(2,:))/N]*c3; %Align average heading
```

The scaling factors c1, c2, and c3 determine how much attraction, repulsion, and velocity alignment can influence the current velocity. vlimit determines the maximum velocity of the voids.

A fourth parameter can be added to generate some randomness for more realistic movement: v4(:,n) = c4*randn(2,1).

Third, the actual velocity is updated as the sum of v1, v2, v3, and v4, and the resulting change in position given the time step, delta, is calculated:

```
v(:,n) = v1(:,n)+v2(:,n)+v3+v4(:,n); %New velocity of agent n
p(:,n) = p(:,n) + v(:,n) *delta; %New position of agent n
```

Reiterate for all agents for each time step, delta.

Template code can be found on Canvas under Files/Codes. Feel free to modify the code in any way you prefer:

- Matlab version, file name Flocking_Matlab.m
- Python version, file name Flocking_Python.py

(1) Explain how each scaling factor (c1, c2, c3, c4) affects the flocking behavior. Back up your claims through simulations, graphs, and/or videos. (25 points)

(2) Introduce obstacles in your environment, and discuss the emergent behavior. With a high attraction scaling factor the swarm should tend to stay as one, with a lower scaling factor it may split up to circumvent the obstacle. *Hint: The easiest way to add an obstacle is to add a static agent with repulsion: all of this may be easier to simulate if you add a barrier of repulsion to contain the swarm within a limited set of coordinates.(25 points)

Paper Review (50 points)

The paper "Solving the shepherding problem: heuristics for herding autonomous, interacting agents" by Strombom *et. al* (J. R. Soc. Interface, 2014), utilizes several random walk models we learned in class, to classify animal search strategies. You can find the paper on Canvas under Files/Paper Reviews/rsif.2014.0719.pdf.

For this part of the homework set, download the paper from Canvas, read it carefully and write a couple of sentences on each of the following items:

- What do you feel the main contribution of this paper is? (10 points)
- What's the essential principle that the paper exploits? (10 points)
- Describe one major strength of the paper. (10 points)
- Describe weakness of the paper. (10 points)
- Describe one future work direction you think should be followed. (10 points)

The point of the reviews is demonstrate your understanding of the paper. It is not to regurgitate the paper but to identify what *you think* is the key concept to learn from the paper and what your opinion is of the strength/weakness of the idea and or paper. We are looking for thoughtful and insightful reviews, that demonstrate depth in your reading and thinking about the paper.