Simulation of Starling murmurations

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1   Abstract

In this report, we present a mathematical model to simulate the phenomenon of Starling Murmuration. This is often referred to as Boids, which was an artificial life program created by Craig Reynolds in 1986 to simulate this beahvior.
There are all sorts of complex rules which decide how the starlings interact with each other and give rise to the phenomenon. In this project, we have considered only a few of those rules, so as to keep the complexity intermediate while, at the same time, keeping the simulation as close to the real phenomenon as possible.

2   Introduction

Murmuration refers to the phenomenon that results when hundreds, sometimes thousands, of starlings fly in swooping, intricately coordinated patterns through the sky. Starlings have a remarkable ability to maintain cohesion as a group in highly uncertain environments and with limited, noisy information.
Starlings pay attention to a fixed number of their neighbors in the flock, regardless of flock density. When uncertainty in sensing is present, interacting with six or seven neighbors optimizes the balance between group cohesiveness and individual effort.
Here, we try to model this behavior, assuming that this behavior is governed by three rules, namely, Short range repulsion, steering towards the average heading of neighbours and Long range attraction. We computationally simulate the phenomenon by modelling each bird as an independent agent communicating and cooperating with other neighbouring agents. Using this simulation we measure from a realistic simulation the average energy spend by each bird, the angular momentum and the force that each bird has to withstand in a typical flight ritual.

3 Simulation

In the subsequent article, we'll refer to the bird as an **boids**. Each agent has certain properties, certain rules that govern the overall behavior of the flock and certain updation rules, according to which the properties of the agents are updated without violating the rules governing the overall flock behavior.

3.1 Properties of a boid

The basic properties of an boid are:

1. Mass

2. Current Coordinates

3. Speed

4. Direction of heading

5. Neighbouring agents

There will be certain upper limits on how fast the agent can go, i.e Speed, and also on how fast the agent can turn, i.e. the angular velocity of the boid, to make the simulation more realistic.

3.2 Rules

The basic rules that governs the flocking behavior of starlings are:

1. **Seperation** - Steer to avoid crowding local flockmates

2. **Alignment** - Steer towards the average heading of local flockmates

3. **Cohesion** - Steer to move towards the average position of local flockmates

Other rules like predator avoidance and obstacle avoidance can also be implemented.

3.3 Updating Properies

The parameters of an agent are updated based on the rules stated above. These updates are done simultaneously for all agents to ensure the flock-like behavior.

Since, continuous time updation is not possible for the simulation, we update the parameters of the agents at a regular interval of approximately 0.02 seconds, i.e with a frequency of 50 Hertz.

3.3.1 Seperation

Here we need to ensure that the boids don't come too close together, i.e. to avoid collision. We can define a certain distance d and if the distance between boids is less than this then we can update a seperation vector and add it to the current location to increase the seperation and avoid collision. Let S_j be the seperation vector for boid b_j, Pj be its postion vector and P is the position vector of a general boid.

Therefore, for all boids in the neighbourhood :

$$S = S - (P - P_j)$$

3.3.2 Alignment

Let V_i be the velocity of boid b_i. Let perceived velocity of boid b_j is V_{pj}.

$$V_{pj} = \sum_{n=1}^{N} V_i$$

After this velocity is calculated, we update the velocity of the boid 'j' as :

$$= (V_{pj} - Vj)/k$$

,where 'k' is a factor to avoid immediate change in velocity and make the change look more realistic.

3.3.3 Cohesion

Boids tend to fly towards the centre of mass of their surrounding boids. The number of boids which influence this decision are pre-decided to a certain number N.

This centre is calculated as the average of of position vectors of the neighbouring boids.

$$C_j = \sum_{n=1}^{N} P_n$$

And the new vector offset of the $boid_j$ is given by C_j/N - current position

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4 References

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