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DESIGN PRACTICES IN CS

Project 2-Simulator for Starling Murmuration

MATHEMATICAL MODELLING

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INTRODUCTION

This is a mathematical model for implementation of a simulator for **Starling Murmuration**. In this document we will look at certain aspects of Murmuration in starlings like:-

- How does each bird decides it speed and direction to move?
- Does the movement of a bird depends on other birds also?
- What happens at an individual level for each bird?
- On what all factors does the movement of a bird depends?

FACTORS DECIDING THE MOVEMENT OF BIRDS

Though the actual movement of starlings depend on various factors but for a very basic model we could assume that the movement of each starling depends mainly on these three factors:-

- **Seperation**- Steer to avoid crowding neighbours.
- **Alignment**- Steer towards the average heading of local flockmates.
- **Cohesion**- Steer to move toward the average position (center of mass) of local flockmates.

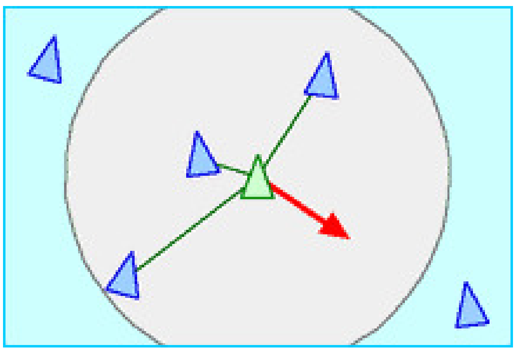

Figure 1: Seperation Effect: The bird tends to move away from crowding neighbours

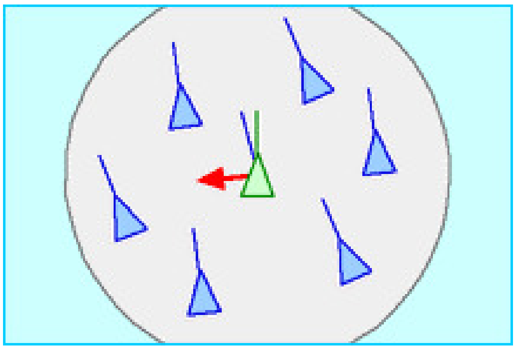

Figure 2: Alignment Effect: The bird tends to towards the average velocity of its neighbours

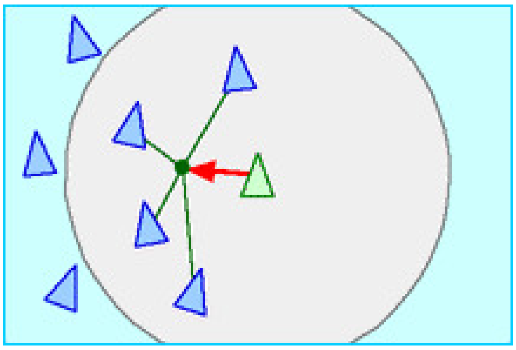

Figure 3: Cohesion Effect: The bird tends to move towards the center of mass of the neighbours

Apart from these, more advanced models could also report the effect of fear, emotions, change of leadership, escaping an enemy, looking for food etc.

Calculating the position of a boid

Suppose the position of a boid in 3D space is given (x, y, z). Now to find the new position of boid after time δt we need to have the velocity of the boid. If we have the velocity of boid v_x, v_y, v_z in X, Y, Z direction respectively then the new position of boid, let $(x_{new}, y_{new}, z_{new})$ is given by

$$x_{new} = x + v_x * (\delta t)$$

$$y_{new} = y + v_y * (\delta t)$$

$$z_{new} = z + v_z * (\delta t)$$

Calculating the velocity of boid

As described above the velocity of each boid depends on three factor that are Seperation, Alignment, Cohesion.

Suppose $N(r)$ is the list of all the boids which are neighnours of a given boid with position p and velocity v, within a circle of radius r, and we know the position and velocity of each boid present in list.

To account for the affect of **Seperation Factor** on the velocity of boid. We take a rather small radius around boid$r$ let say r_1 and find the list of all the neighbours in that given circle. After that we find the mean position of all the boids given in $N(r_)$ and find a vector from the position of original boid to that mean. Now as a result of seperation effect we will have a velocity in opposite direction of this vector in order to avoid crowding. Let say $v_{seperation}$ is the effect on velocity due to seperation and is given by

$$v_{seperation} = seperation_{factor} * (p - \frac{\sum_{n \epsilon N(r_1)} position(N(n))}{N(r_1)})$$

where $seperation_{factor}$ would be negative as boid moves away from average position to avoid crowding.

To account for the affect of **Alignment Factor** on the velocity of boid. We take a radius around boid r let say r_2 and find the list of all the neighbours in that given circle. After that we find the mean velocity of all the boids given in $N(r_2)$. Let say $v_{alignment}$ is the effect on velocity due to alignment and is given by

$$v_{alignment} = alignment_{factor} * (\frac{\sum_{n \epsilon N(r_2)} velocity(N(n))}{N(r_2)})$$

where $alignment_{factor}$ would be positive as boid moves in the direction of average velocity of neighbours.

To account for the affect of **Cohesion Factor** on the velocity of boid. We take a radius around boid r let say r_3 and find the list of all the neighbours in that given circle. After that we find the mean position of all the boids given in $N(r_3)$ and find a vector from the position of original boid to that mean. Now as a result of cohesion effect we will have a velocity in same direction of this vector in order to move towards the centre of mass of neighbours. Let say $v_{cohesion}$ is the effect on velocity due to cohesion and is given by

$$v_{cohesion} = cohesion_{factor} * (p - \frac{\sum_{n \epsilon N(r_3)} position(N(n))}{N(r_3)})$$

where $cohesion_{factor}$ would be positive as boid moves towards the average position of its neighbours.

Taking in account all the three factors we can say that the new velocity of a boid v_{new} is given by

$$v_{new} = v_{old} + v_{seperation} + v_{alignment} + v_{cohesion}$$

Now, using these velocities we could easily calculate the new positions of the boids and trace the trajectory in which they move. We could also change the factors like $alignment_{factor}, seperation$ to make some variations in the movements of the boids.

References

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