MATHEMATICAL MODELLING OF STARLING FLOCKING

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A mathematical model to design and implement a simulation of flocking of starlings.

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Chapter 1

Flocking Rules

Flocking behavior is the behavior exhibited when a group of birds, called a flock, are foraging or in flight. There are parallels with the shoaling behavior of fish, the swarming behavior of insects, and herd behavior of land animals.
Basic models of flocking behavior are controlled by three simple rules:
1. Separation : Steer to avoid crowding birds of the same colour.
2. Alignment : Steer towards average heading of birds of the same colour.
3. Cohesion : Steer to move toward he average position of birds of the same colour.

1.1 Rules

The following rules determine the flocking simulation:

1. Boids try to fly towards the centre of mass of neighbouring boids.
The "centre of mass" is the average position of all boids. Assume we have N boids, called A_1, A_2, ..., A_N and the position of K_{th} boid is determined by A_K.position. The "centre of mass" is given by :
c = (A_1.position + A_2.position + ... + A_N.position) / N
However the boid moves towards it's 'percieved' centre of mass. Thus for boid K (0 < K <= N), the percieved centre of the boid is :
pc_K = (A_1.position + A_2.position + ...+ A_{K-1}.position+ ....+ A_N.position) / N-1

PSUEDOCODE :
PROCEDURE rule1(boid b_K)
Vector pc_K
FOR EACH BOID b
    IF b != b_K THEN
    pc_K = pc_K + b.position
    END IF
END
pc_K = pc_K / N-1
RETURN (pc_K - b_K.position) / 100
–If we want to move the bird 1 percent towards the centre.
END PROCEDURE
This is the first vector offset v1 for the bird.

2. Boids try to keep a small distance away from other objects (including other boids). The birds should not collide with each other. If a boid is within a predefined distance of another boid, we have to move it away. This is done by subtracting from a vector c the displacement of each boid which is near by.

PSUEDOCODE :
PROCEDURE rule2(boid b_K)
Vector c = 0;
FOR EACH BOID b
    IF b != b_K THEN
    c = c - (b.position - b_K.position)
    END IF
END IF
END
RETURN c
END PROCEDURE

3. Boids try to match velocity with near boids. Similar to rule 1 we calculate the percieved ve-

locity of the birds. We calculate a 'perceived velocity', pv_K, then add a small portion (about an eighth) to the boid's current velocity. pc_K = ($A1_1$.velocity + $A1_2$.velocity + ... + $A1_{K-1}$.velocity + $A1_{K+1}$.velocity ... + $A1_N$.velocity) / N-1

PSUEDOCODE :
PROCEDURE rule3(boid b_K)
Vector pv_K
FOR EACH BOID b
    IF b != b_K THEN
    v_K = pv_K + b.velocity
    END IF
END
pv_K = pv_K / N-1
RETURN (pv_K - b_K.velocity) / 8
END PROCEDURE

1.2 Range

Each bird has a detection and separation range. The applet program as the option of displaying or hiding the ranges. The detection range is the distance at which birds can detect predators, obstacles, foods and other birds. The separation range is the distance at which a flock of birds might split up to avoid a predator, obstacle or bird. Until something falls within a birds detection range, it will not react to it.
The rules are explained using range as follows :-
1. $\boldsymbol{Separation}$: Birds are repelled by birds of different colours and obstacles. The closer the bird, the greater the repel effect. This causes birds to turn away from predators, obstacles and different colour birds.

2. $\boldsymbol{Alignment}$: In a flock of birds that are all the same colour, each bird will try to match the direction of birds around it that it can detect. If some of the birds in a flock detect an obstacle, they will turn. This causes the rest of the flock that can't even detect the obstacle to also turn away from it.

3. $\boldsymbol{Cohesion}$: Birds within a flock are attracted to each other as long as they are within the detected range, but outside the separation range. If there are too many birds in the flock, the separation range will need to be increased.

1.3 Multiple boids simulation (together) :

Threading used for a certain number of boids so that the rendering is done in parallel. The number of birds is not kept equal to the number of birds since that puts extra pressure on the processor as the draw() function somewhat suffers.

Chapter 2

Features and Logistics

2.1 Features :

2.2 1. Goal Setting

2.2.1 Affinty or repulsion towards a particular place

2.3 2. Speed Limit :

2.3.1 Bound

2.3.2 Hurdles

2.4 3. Scattering

2.4.1 Prey attack

2.4.2 Tendency away from a particular place