STARLING MURMURATION

A Mathematical and Programmable Model for the simulation of Flocking of boids

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COP290-Spring(18)

INTRODUCTION

This project is to model and simulate a the fascinating phenomenon of "*Starling Murmuration*". We will computationally simulate the phenomenon by modelling each bird as an independent agent communicating and cooperating with other neighbouring agents. Our objective will be to 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.

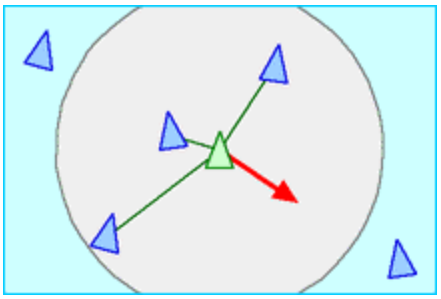
We will study and simulate *Boids*, which is basically an artificial life program, which simulates the *Flocking* behaviour of *Starlings*.

BOIDS

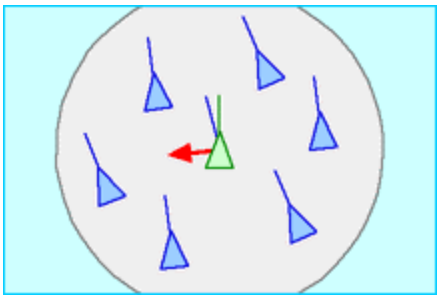
The name "boid" corresponds to a shortened version of "bird-oid object", which refers to a bird-like object.

Boids is an example of emergent behavior; that is, the complexity of Boids arises from the interaction of individual agents (the boids, in this case) adhering to a set of simple rules. The rules applied in the simplest Boids world are as follows:

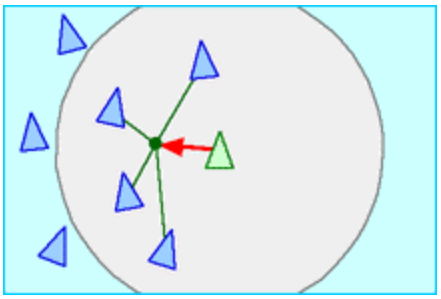
- **Separation**:- steer to avoid crowding local flockmates



- **Alignment**:- steer towards the average heading of local flockmates

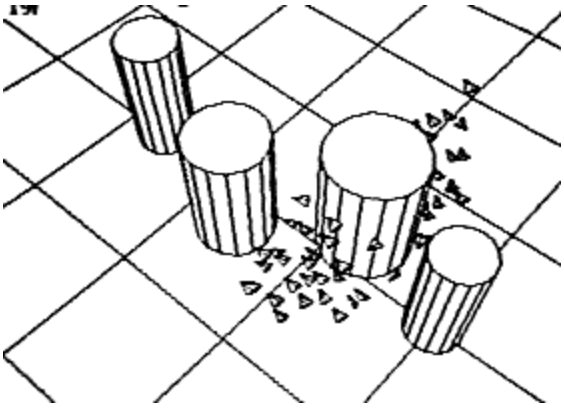


- **Cohesion**:- steer to move toward the average position (center of mass) of local flockmates



Following are some of the more complex and advanced features:

- Obstacle avoidance

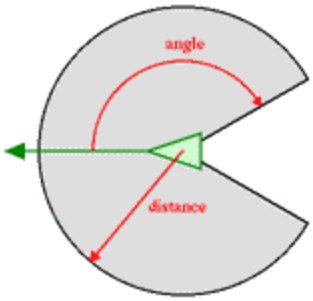


(Simulated Boid flock avoiding cylindrical objects)

- Goal Seeking
- Fear and its effects
- Transmission of emotion between animals (through pheromones modelled as

particles in a free expansion gas)
- A complementary force to the alignment called the change of leadership (defines the chance of the boid to become a leader and try to escape)

Each boid has direct access to the whole scene's geometric description, but flocking requires that it reacts only to flockmates within a certain small neighborhood around itself. The neighborhood is characterized by a distance (measured from the center of the boid) and an angle, measured from the boid's direction of flight. Flockmates outside this local neighborhood are ignored. The neighborhood could be considered a model of limited perception (as by fish in murky water) but it is probably more correct to think of it as defining the region in which flockmates influence a boids steering.



A Boid's Neighborhood

Movement of Boids can be characterized as either:

1) Chaotic (splitting groups and wild behaviour) or
2) Orderly.

Unexpected behaviours, such as splitting flocks and reuniting after avoiding obstacles, can be considered "*Emergent*"

Applications of Boids:

- Computer graphics (providing realistic-looking representations of flocks of birds and other creatures)

- For direct control and stabilization of teams of simple *Unmanned Ground Vehicles* or *Micro Aerial Vehicles* in Swarm Robotics
- To automatically program Internet multi-channel radio stations
- Visualizing information
- For optimization tasks
- Cellular Automation
- Data Mining
- Multi-Agent Reinforcement Learning
- Screensavers :P

FLOCKING (BEHAVIOUR MODELING)

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.

We're talking about Modeling the Behaviour..

From the perspective of the mathematical modeller, "flocking" is the collective motion of a large number of self-propelled entities and is a collective animal behavior exhibited by many living beings such as birds, fish, bacteria, and insects. It is considered an emergent behavior arising from simple rules that are followed by individuals and does not involve any central coordination.

With the three simple rules of Separation, Alignment and Cohesion, the flock moves in an extremely realistic way, creating complex motion and interaction that would be extremely hard to create otherwise.

Measurements are done using Computer Analysis of High Speed Cameras

ALGORITHMIC COMPLEXITY

A basic implementation of a flocking algorithm has complexity $O(n^2)$ - each bird searches through all other birds to find those which fall into its environment

This is because as there is no central control and each bird behaves autonomously, each bird has to decide for itself which flocks to consider as its environment. Usually environment is defined as a circle (2D) or sphere (3D) with a certain radius (representing reach)

IMPROVEMENT:

One possible improvement is $O(nk)$, where we use the "Bin-Lattice Spatial Subdivision Approach", in which the spatial data structure allows entire area where the flock can move in, to be divided into a large number of bins where each bin stores which birds it contains. This allows the boids to be kept sorted by their location. Each time a bird moves from one bin to another, the lattice has to be updated. Here, k would be the number of surrounding bins to consider, and bin access time as O(1)

MATERIALS

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PROCEDURE

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DATA

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RESULTS

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CONCLUSION

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