MATHEMATICAL MODELING OF BIRD GROUP BEHAVIOR

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Abstract

In this paper we present theoretical framework for design and analysis of distributed flocking algorithms. We demonstrate the algorithm embodies all three rules of Reynolds. We show that migration of flocks can be performed using a peer-to-peer network of agents, i.e., "flocks need no leaders."

1 Introduction

Few things in nature is as impressive as how some animals seems to be able to organize themselves into larger groups so effortlessly.Starlings are small passerine birds in the family Sturnidae.As starlings gather in the evenings to roost, often they will participate in what is called a murmuration — a huge flock that shape-shifts in the sky as if it were one swirling liquid mass. Often the behavior is sparked by the presence of a predator like a hawk or peregrine falcon, and the flock's movement is based on evasive maneuvers. There is safety in numbers, so the individual starlings do not scatter but rather are able to move as an intelligent cloud, feinting away from a diving raptor, thousands of birds changing direction almost simultaneously. One of the first stepping stones to get to an understanding of flocking behaviour is to be able to simulate it.The first flocking-behavior simulation was done on a computer by Craig Reynolds in 1986 he called his simulation program: "Boids". It's still to this day to most used model for simulating flocking behaviour. This project consists of a world of BOIDS, each having its own intelligence to control its movement. Each BOID is capable of deciding its own path to take depending on where the rest of the flock is and how bunched up its neighbors are.

2 BOIDS

A representation of a bird in flocking simulations. The word is most commonly used in the context of Boids, the original computer simulation of flocking behavior by Reynolds and derivatives of Boids. The name "boid" corresponds to a shortened version of "bird-oid object", which refers to a bird-like object. Each boid object should at least have the following attributes to describe the state it is in.

Location The x and y coordinates of the current position of the boid

Velocity The speed of which the boid is traveling.

3 Rules

Reynolds makes a comparison to a particle system, meaning that many fea- tures are similar. One vast difference, that gives the modelling of flocking be- haviour an additionally complex geometrical state, is the fact that each and every agent has a direction. Reynolds also states that it is difficult to point out further differences between a particle system and a model of flocking behaviour, apart from the knowledge that animal behaviour is a complex matter, which is hard to understand and fully describe.

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

alignment
cohesion

3.1 Separation

Pushes boids apart to keep them from crashing into each other by maintaining distance from nearby flock mates. Each boid considers its distance to other flock mates in its neighborhood and applies a repulsive force in the opposite direction, scaled by the inverse of the distance.

3.2 Alignment

Drives boids to head in the same direction with similar velocities (velocity matching).Calculate average velocity of flock mates in flock and steer towards that velocity.

3.3 Cohesion

Keeps boids together as a group.Each boid moves in the direction of the average position of its neighbors.Compute the direction to the average position of flock mates and steer in that direction.

3.4 Mathematical Modeling

The math behind the BOIDS is not all that complicated. The BOIDS attempt to match velocity, orientation, and average position of the BOIDS that are located in within a certain radius.
The first problem is of separation. As mentioned before, each BOID has its "safe space". If another BOID enters this safe space, the BOID will attempt to move away until it is comfortable again. This means

$$v_2 = v2 - \frac{\sum_i^n (X_i - X_j)}{n}$$

where xj is position of current boid
The next behavior of the BOIDS is to attempt to match the velocity and orientation of its near neighbors. So,

$$v_3 = \frac{\sum_i^n (v_i)}{n} - vj$$

where vj is vellocity of current boid
The last type of BOID interaction is the attempt to flock together towards an average position of the nearby group. Simply averaging the position of the neighboring BOIDS and then

$$v_3 = \frac{\sum_i^n (x_i)}{n} - xj$$

The oveall speed of boid from these commulative effect is v = v1 + v2 + v3. In our implementation of Boid we also have effect of walls so that bird to donot lost away from visible area. Thus V = v - wallforce
All these three rules and wall effects guides the boid simulation

3.5 Conclusions

Animal behavior has always been a source of amazement to mankind. This model explainED the theory behind the modelling of flocking behaviour and present and discuss a strategy and model for a flock with individual agents. The model is based on simulating the behavior of each bird independently. Working independently.Each BOID is capable of deciding its own path to take depending on where the rest of the flock is and how bunched up its neighbors are.