Investigating the Impact of a Genetic Algorithm on Inter-Flock Dynamics

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Abstract

Here is my abstract and where i shall be placing the content of soon.

1 Introduction

1.1 General Introduction and Background Information

Flocking is a behaviour in which all social organisms engage; it is the common movement of organisms guided by both social and environmental pressures. These flocks of organisms can be found interacting with other flocks in nature, and the way they interact is as varied as it is interesting.

Producing flocking behavior that recreates those found in nature is an endeavor already undertaken and in constant update. The field, taking off in 1987 with Craig Reynolds' influential paper (Reynolds, 1987), shows how realistic flocking behaviour can already be achieved by applying 3 simple rules to each boid ('boid' as coined in the prior paper, this is essentially an agent) in regard to its neighbours: Cohesion, movement toward the average position; Alignment, movement toward the average direction; and Separation, movement to avoid collision.

Since then, the original flocking algorithm has been extended in various ways, with communication techniques, mathematical models for how leadership arises in the flock, as well as models for how consensus is made in a flock. These expansions allow for more complex behaviours and reactions to the enviornment and surroundings.

Learning behaviours have also been added. The behaviour and strategies flocks produce are patterns. This means if a flock can learn and understand those patterns it has a significant advantage over that other flock – an interesting example would be a group of honey hunters and smoke; bees flee the nest if they think there is a fire, the first warning sign to this is smoke, as a group (or flock) they take advantage of this by releasing smoke into the hive. The bees evacuate the nest; they get honey.

This dissemination of new knowledge, either through behaviour or communication is interesting because it can increase the complexity of the reactions the flock has to a given situation. This added complexity may lead to new behaviours that may not have been easily predicted or thought of as something a flock could produce.

1.2 Aim, Objectives and Research Question

Aim To investigate the impact of a genetic algorithm on the dynamic interaction of flocks with each other to see if this has a beneficial effect in comparison to regular flocking algorithms.

Objectives

- To research and evaluate AI techniques, studying their relevance and potential for further development in applying them to flocking algorithms, with particular focus on artificial life techniques.

- To produce an application that models flocking behaviour, and allows the observation and comparison of AI flocking strategies to regular flocking algorithms. This will be developed using the prior identified AI techniques most likely to produce viable flocking behaviours.
- To analyse the effectiveness of strategies that the AI come up with in their interactions with other flocks, comparing and contrasting that to the behavior of standard flocking algorithms.

Research Question What impact can a genetic algorithm have on the dynamic interaction of flocks with each other in comparison to that of regular flocking techniques?

2 Literature Review

2.1 Flocking in Nature - Swarm Behaviour

Flocking algorithms draw a lot of their inspiration from the behaviour of flocks in the natural world (Flake, 1998). As there are many examples of this behaviour in organisms across the planet, there is a lot of information and insight that can be gleaned on how to design these algorithms. Flocks are included in the field of Swarm Behaviour, that is, the study of swarms in the natural world

Decision Making The way decisions are made in a flock emerges is varied. The two main ways are via consensus and leadership. An interesting look at this can be found in the behaviour of pigeons. A study conducted into the behaviour of these birds in a flock (Jorge and Marques, 2012) found that leadership initially emerged from younger pigeons in the flock, but as the flight went on older members of the flock led the group, the paper then goes on to discuss how social versus personal information affects the behaviour of the flock. What this displays, is how the extra experience of older members of the flock is taken advantage of in determining leadership and therefore the actions they take as a flock, in this way they build consensus on their leadership through the choices individual flock members make in their group. This is further confirmed in *'Misinformed leaders lose influence over pigeon flocks'* Watts et al. (2016). What this displays is the interaction between consensus and leadership in making decisions, and demonstrates that they can both be present in the process.

Eusocial Behaviour While not specifically flocking as it pertains to biology, this falls under the bracket of swarm behaviour and has interesting relationships which can inform us on how to expand flocking algorithms in beneficial ways. For example, communication can occur in a variety of ways; ants use pheromones to find shortest paths (Dorigo and Gambardella, 1997); bees use a waggle dance to inform others in the hive of food sources and potential new nest sites (Al Toufailia et al., 2013), and

Dynamic Adaptation to Environmental Pressures

Learning and Curiosity

Flocking and Emergence

The Advantages of Flocking to Species

Why this is relevant This is relevant as it inspires the work done in flocking algorithms and the work of similar fields, which has influence on the design of said algorithms.

2.2 Flocking Algorithm

Flocking algorithms draw inspiration from the natural world, however the design of these algorithms involves mathematical approximations of the behaviours involved, the interactions that take place and the systems overall.

Reynolds Boids In the often cited paper when it comes to discussions of flocks: *'Flocks, herds and schools: A distributed behavioral model'* Reynolds (1987), we see that we have the three main forces that make up a basic flock: Separation, Cohesion and Alignment. These are approximative forces that represent the aggregate motion of a collection of boids (representing flock members, which in turn can represent different species in nature).

Expanded Boids There are many variations of the expanded boids model [insert citations here] dependent upon what is necessary for the research conducted. The expanded model presented by Kawabayashi and Chen (2008) is very useful as their implementation is very clear and displays useful expansions to the model for this research. It adds functionality for running away from predators, attraction to food sources, relations as towards other neutral flocks, the ability to search its surroundings, boundary conditions, and obstacle avoidance. All of which are useful in designing more natural flocking behaviour.

Decision Making In parallel to the way decisions are made in natural flocks, flocking algorithms can also make decisions. An interesting way of producing leadership in an artificial flock can be found in the paper textit'Autonomous Boids' Hartman and Benes (2006). Here they propose the use of an 'Eccentricity' variable to determine leadership in the group in order to make decisions based on the boids proximity to the front of the flock, the closer it is, the higher a chance of leading the flock. This mimics the way that some species of bird, such as starlings, decide on leadership within the group. This leadership can then be used to influence decisions by the rest of the flock.

Learning and Curiosity

2.3 The Interaction of Flocking Algorithms

In the paper *'Simulating Species Interactions and Complex Emergence in Multiple Flocks of Boids with GPUs'* Husselmann and Hawick (2011), multiple flocks, each a different type of boid, are run in a closed environment to see what aspects of species interaction could be reproduced. The

2.4 Genetic Algorithm

The literature on genetic algorithms also matters as this is what will be used to expand upon the capabilities of the flock. There is

2.5 The Potential Effect of AI on Flocking Algorithms

A paper discussing the use of reinforcement learning in a multi-agent system by Jaderberg et al. (2018) displays the potential of AI applied to a group of agents.

2.6 The effect of Genetic Algorithms on Boids

Genetic Algorithms used to improve the boids model is nothing new and provides useful information into how to go about this research. For example in *'Genetic Algorithms for Optimization of Boids Model'* Chen et al. (2006)

2.7 The Interaction of an AI Flock with another Flock

The interaction of an artificially intelligent flock with other flocks is where the research becomes thinner and where the author feels based upon their own background research there is a room for expansion.

3 Methodology

An application was produced to test the hypothesis. This application used the Games Education Framework [reference]

3.1 Application Design

3.2 Test Environment Design

The application simulated an environment, in which two flocks interact (one of which is improved via a genetic algorithm) within a limited space of scarce resources, with the aim of finding out if a flocking algorithm improved by a genetic algorithm can outcompete one without.

3.3 Flocking Algorithm Design

The design of the flocking algorithm was produced through research into how they are produced and came through via an iterartive approach.

The flocking algorithm was originally designed primarily by adapting the example from Shiffman (n.d.). As this was a very clear representation of how to design a basic flocking algorithm from a code perspective. There were also clear areas for improving the efficiency of the algorithm presented too. The most major way was combining the calculations for Alignment, Separation and Cohesion. This was so each boid was not checking against all others for each force calculation, and only needed to check against all other boids once instead of three times; doing that was simple and reduced the requirements for N-Body problem solutions later on.

The boids forces as they are in the program were modelled primarily off of the paper [reference here]. This is a modified version of the expanded boids algorithm, optimised for the environment in which it is placed in. The forces each boid experiences are: Cohesion, Alignment, Separation, Food Attraction and Flock Avoidance. Each of these forces are the multiplication of a unit vector and their respective weight, mathematically represented in Eq.1

$$\boldsymbol{ForceVector} = \boldsymbol{v} \cdot \boldsymbol{w} \tag{1}$$

3.3.1 Cohesion

This is the first of the boid forces

$$\begin{aligned} \boldsymbol{\hat{v}_{coh}} &= \frac{LFCVector}{|LFCVector|} \\ \boldsymbol{w_{coh}} &= \frac{(|LFCPos - BoidPos|)^2}{30 \cdot FlockSize} \end{aligned} \tag{2}$$

3.3.2 Alignment

$$\begin{aligned}
\hat{\boldsymbol{v}}_{\boldsymbol{ali}} &= \frac{LFVelVector}{|LFVelVector|} \\
\boldsymbol{w}_{\boldsymbol{ali}} &= \frac{1}{10 \cdot |(LFCPos - BoidPos)|}
\end{aligned} \tag{3}$$

3.3.3 Separation

$$\begin{aligned}
\hat{\boldsymbol{v}}_{\boldsymbol{sep}} &= -\frac{ClosestNeighbourVector}{|ClosestNeighbourVector|} \\
\boldsymbol{w}_{\boldsymbol{sep}} &= 0.025 \cdot \Big(\frac{NeighbourCount}{|ClosestNeighbourVector|}\Big)^2
\end{aligned} \tag{4}$$

3.3.4 Food Attraction

$$\begin{aligned}
\hat{\boldsymbol{v}}_{\boldsymbol{fda}} &= \frac{ClosestResourceVector}{|ClosestResourceVector|} \\
\boldsymbol{w}_{\boldsymbol{fda}} &= 0.0025 \cdot |ClosestResource|^2 + \frac{36}{|ClosestResource|^2}
\end{aligned} \tag{5}$$

3.3.5 Flock Avoidance

$$\begin{aligned}
\hat{\boldsymbol{v}}_{\boldsymbol{fla}} &= -\frac{OtherFlockVector}{|OtherFlockVector|} \\
\boldsymbol{w}_{\boldsymbol{fla}} &= \frac{300}{|AvgOtherFlockPos|}
\end{aligned} \tag{6}$$

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