Predator-Prey Simulation Using Boids Model

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Collective behaviour course research seminar report

December 3, 2023

The collective behaviours observed in nature, such as flocking, herding, or schooling, often serve as adaptive strategies that enhance the survival chances of individuals within a group. Understanding these natural behaviors serves as inspiration for designing autonomous agents capable of sophisticated interactions within a simulated environment. Our goal is to simulate prey and predator with different predator tactics (attack center, attack nearest, attack isolated, attacks from various directions, constant bearing hunting), escape maneuvers (split, hourglass, herd, vacuole, flash expansion, fountain) and parameters (perception radius, moving speed, turning speed) in order to conclude how different escape maneuvers affect predator's success.
This research paper however, will only focus on the basic boid (bird-oid object) simulation. This simulation will serve as a foundation for the more complex simulations in the future.

Collective Behaviour | Boids | Simulation | Prey-Predator | Escape patterns

Introduction

One of the most striking patterns in biology is the formation of animal aggregations. Classically, aggregation has been viewed as an evolutionarily advantageous state, in which members derive the benefits of protection, mate choice, and centralized information, balanced by the costs of limiting resources [2]. We will presume the most common hypotheses, which is that flocking evolved in order to provide defense against predators, and conclude with which flocking behaviour is the most effective for prey and predator. Our research is based on Emergence of splits and collective turns in pigeon flocks under predation [1], which we will extend by providing concrete results in the predator and prey simulation. This research is similar to Jure Demšar and Iztok Lebar Bajec's Comparison of (predator) tactics [3]. The main difference between the mentioned research and ours is the use of boids algorithm instead of fuzzy logic.

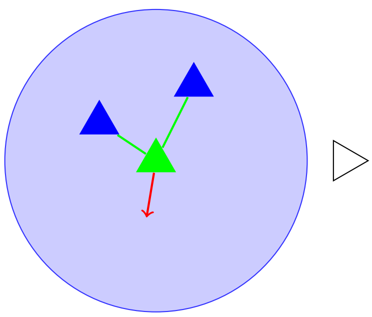
The flocking behaviour can be simulated in different ways. For example Heppner and Grenader [4] were modeling bird's behaviour with stohastic nonlinear differential equations. Oweis, Ganesan and Cheok [5] took a different approach and modeled birds with a centralized logic (as in the server-client architecture). In 1987, Reynolds [6] proposed a simple algorithm, which was groundbreaking at the time, to model the flocking behavior of birds, herding of sheep, and similar phenomena, known as the Boids (Bird-oid objects) model. In contrast to controlling the interactions of the entire flock, the Boids simulation focuses on dictating the behavior of each individual boid. Despite consisting of a few simple rules, this algorithm produces complex and lifelike behaviors similar to those observed in nature.

Our paper centers on the implementation of a predator-prey behavior utilizing a Boids simulation.

Methods

As a starting point, a basic boids model has been implemented, which is based on three simple rules:

1. Avoid collisions.



2. Maintain the same heading and speed as the neighboring boids.

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Predator-prey interactions is of significant importance in biology and nature itself. The insights gleaned from this research can offer more than a theoretical understanding; they pave the way for the design and optimization of autonomous agents capable of adaptive and context-aware behaviors. The applications range from research in biology to simulations of large amounts of boids found in computer graphics.

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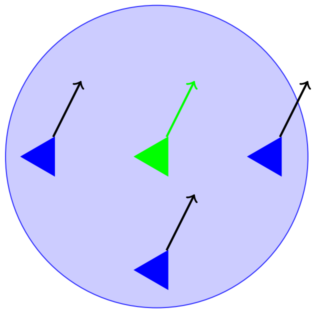
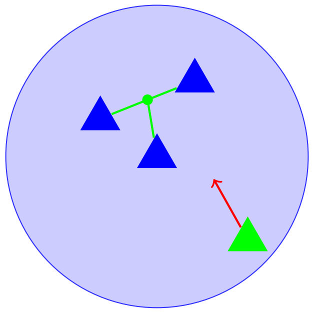


3. Gravitate toward the center of the flock.



Basic boids implementation. Each boid B has the following properties:

1. position - a vector in $\mathbb{R}^2$, denoted by $position(B)$,
2. velocity - a vector in $\mathbb{R}^2$, denoted by $velocity(B)$,
3. acceleration - a vector in $\mathbb{R}^2$; used exclusively for the internal computation of the boid's velocity and not for behavioral logic.

With regards to behavioral logic, we also assign the following attributes to all boids:

1. perception radius (denoted by r_P)
2. separation radius (denoted by r_S, also note that $r_S < r_P$)

The *Euclidean distance* (1) is used for computing the distance between boids.

$$d(p,q) = \sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2};\ p,q \in \mathbb{R}^2 \tag{1}$$

To avoid the computation of the costly square root of a real number, we utilize an equivalent formula (2):

$$d(p,q)^2 = (p_1 - q_1)^2 + (p_2 - q_2)^2;\ p,q \in \mathbb{R}^2 \tag{2}$$

Each step of the simulation loop updates the direction of a boid, which is then applied to its acceleration, determining the actual velocity for all boids.

The direction for collision avoidance, also known as *separation*, for boid B is computed by the following formula (3):

$$direction = \sum_{i=1}^{n} position(B) - position(B_i) \tag{3}$$

where i-th boid B_i is a boid such that: $d(position(B), position(B_i))^2 < r_S^2$. This effectively means that boid B will move away (in the opposite direction) from the boids which are too near (closer than the specified r_S).

The direction for *alignment* for boid B is computed as (4):

$$direction = \left(\frac{\sum_{i=1}^{n} velocity(B_i)}{n} - velocity(B) \right) / \ 8 \tag{4}$$

where i-th boid B_i is a boid such that: $d(position(B), position(B_i)^2 < r_P^2)$ (i.e., B_i is B's neighbour). First, the average velocity of all neighboring boids is computed (denoted v_{avg}). The velocity of current boid B is then subtracted from v_{avg}, such that a vector in the direction from $velocity(B)$ to v_{avg} is obtained. Adding such a vector to the $velocity(B)$ would result in $velocity(B)$ being equal to the v_{avg}. Since this result is not desired, direction is lastly divided by a constant 8.

The direction for *cohesion* for boid B is computed like so (5):

$$direction = \left(\frac{\sum_{i=1}^{n} (position(B_i) - position(B))}{n} \right) / \ 100 \qquad [5]$$

where i-th boid B_i is a boid such that: $d(position(B), position(B_i)^2 < r_P^2)$ (i.e., B_i is B's neighbour). In this formula a centroid to the neighboring boids is computed, which is then divided by 100. The reasoning behind the constant 100 is that on every update, each boid would move 1% towards the centroid.

Results

We have successfully implemented the model described in the previous section. Correct behaviour was confirmed with the help of special debug draw commands on top of the boids. We present 3 screenshots of the simulation at steps $0, 50$ and 100. We can see that at first boids are in random positions, but as the simulation progresses, they start forming groups (**cohesion**) which generally go in the same direction (**alignment**). Eventually, a single group is formed.

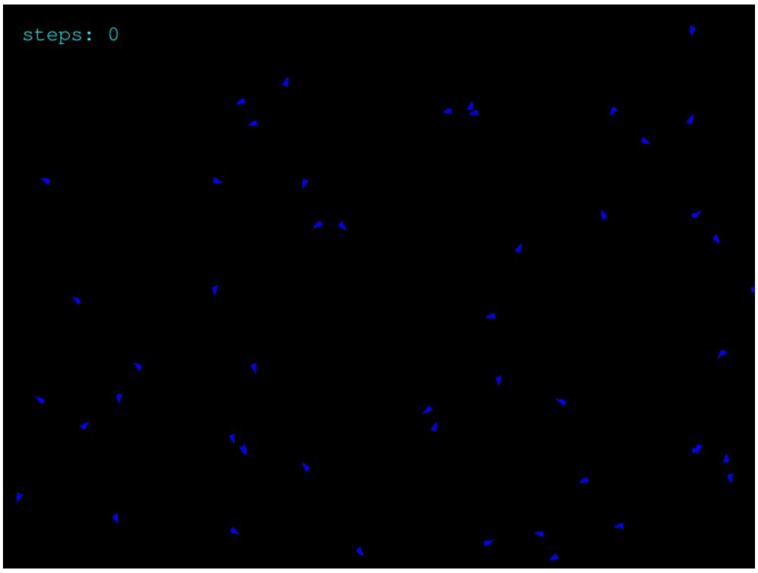


Figure 1. Boids simulation at step 0

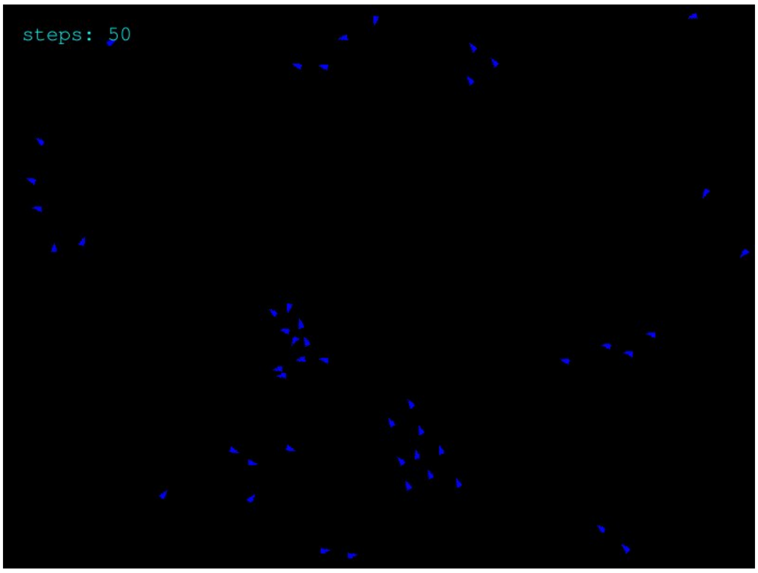


Figure 2. Boids simulation at step 50

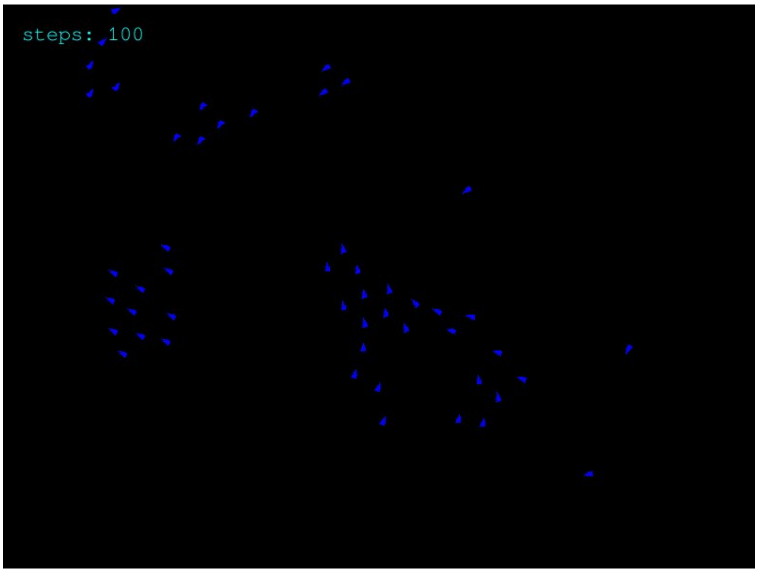


Figure 3. Boids simulation at step 100

Discussion

This concludes the initial implementation of boids flocking simulation. The following aspects remain to be implemented:

1. use a more realistic perception (300 degrees instead of 360)
2. take boid turn speed into account in computation
3. take information propagation into account
4. implement predators
5. implement escape maneuvers
6. implement logic for determining success of predators

CONTRIBUTIONS. Matija Ojo: Initial boid implementation and report fixes, Miha Krajnc: Refactor boid implementation and report, Janez Kuhar: Initial version of report, Marko Adžaga: Report

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