Enhancing Predator Avoidance through Flocking Behavior: A Computational Simulation Study

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Abstract

In our paper we aim to investigate the impact of flocking behavior on predator avoidance in a simulated environment. In Order to single out the flocking behavior and test its effects we ran a series of simulations and analyzed how flocking changed average distance from predators, catch rates, and survival times of prey individuals. The results suggest that flocking behavior contributes to increased predator avoidance, as evidenced by a higher average distance, lower catch rates, and extended survival times compared to solo behavior. These findings emphasize the evolutionary advantage gained by complex collective behaviors and our understanding of such systems.

Introduction:

In nature, survival often depends on an individual's ability to evade predators. Many species have evolved various mechanisms, including group behaviors, to increase their chances of escaping predation. Flocking behavior, observed in a variety of animals such as birds, fish and mammals, is one such collective strategy that has been hypothesized to enhance predator avoidance(Cresswell, 1994). Flocking involves the coordinated movement of individuals within a group such as the distance between each individual and the general orientation of the group, when combined by the entire collective these movements can lead to emergent properties that may deter or confuse predators and thus help prey avoid them.

In this study, we aim to investigate the impact of flocking behavior on predator avoidance using a simple computational simulation. By simulating prey individuals with and without flocking behavior in the presence of a predator, we are able to quantify key factors such as average predator distance, catch rates, and survival times.

Methods:

To better our understanding of flocking behavior on predation we created a computational simulation environment based on similar studies(*Reynolds, 1987*). The simulation consisted of prey and predator individuals represented as agents within a two-dimensional virtual space. the behaviors of both prey and predators were governed by predefined rules.

The simulation was run using the python library PyGame with the aforementioned behaviors using the built in physics engine provided by that library.

<u>Pray movement was dictated by 4 main rules:</u>

- Alignment- The alignment rule aimed to mimic the tendency of pray to align side by side when in movement.
  Alignment= (∑Velocities of Neighbors)/Total Neighbors − Current Agent's Velocity
- Cohesion- The cohesion rule aimed to move the agents to the centroid of nearby neighbors thus simulating the tendency of individuals in a flock to stay together.
  Cohesion=(Centroid of Neighbors−Current Agent's Position)/Distance
- Separation- The separation rule aimed to prevent prey agents from getting too close to their neighbors, mimicking personal space and avoiding collisions.
  Separation=(∑(Current Agent's Position−Neighbor's Position))/Distance
- Predator Avoidance- The predator avoidance rule enabled prey agents to detect the presence of predators within a certain distance and steer away from them.
  Predator Avoidance=(Current Agent's Position−Predator's Position)/Distance

<u>Predator behavior was dictated by 2 main rules:</u>

- Seeking nearest prey- The predator will continuously move towards the nearest prey changing direction if a different prey gets closer then the one being chased.
  Direction to Nearest Prey=(Nearest Prey Position−Predator Current Position)/Distance
- Catching prey- The predator checks for collisions with prey agents and applies a 0.5-seconds delay between each removal of caught prey. This is aimed to mimic the time it takes for a predator to eat prey before continuing the hunt.

We implemented two experimental scenarios: one with prey individuals exhibiting flocking behavior(Fig.1) and another with solitary prey individuals(Fig.2). In the flocking scenario the movement of each prey agent was governed by all 4 rules and in the solitary scenario solely by the Predator Avoidance rule. Each individual simulation consisted of 30 prey agents(blue) and one predator(red). The locations of both were randomized and the simulation stopped once the prey population was reduced to 10% of its original size in order to maintain the main window for data collection to be when enough agents are flocking together. Each scenario was repeated 10 times during which the following data was collected: distance from predator for all remaining prey, time survived from all remaining prey and the amount of prey caught at each in-game interval.

Fig. 1

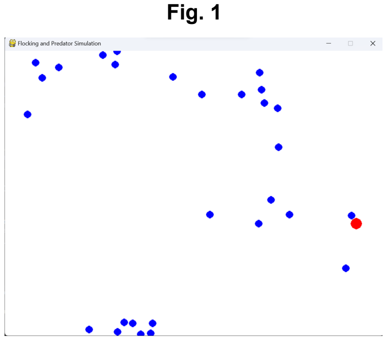
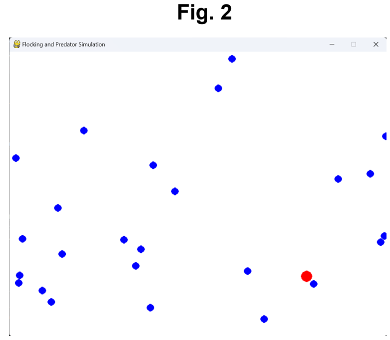


Fig. 2



Results:

Analyzing the data of the simulation leads us to conclude that flocking behavior does indeed lead to higher predator avoidance. In all 3 metrics recorded we observed more favorable results with flocking as opposed to without. Prey individuals exhibiting flocking behavior maintained a marginally higher average distance (flock mean distance: 380.3) from predators compared to those that remained solitary (solo mean distance: 365.53)(Fig .1)

This Increased distance might be attributed to the collective movement of the flock, causing more individuals to be at a greater distance from the predator at any given moment(Fig. 2) as well as making it more challenging for the predator to single out prey.

Fig. 1

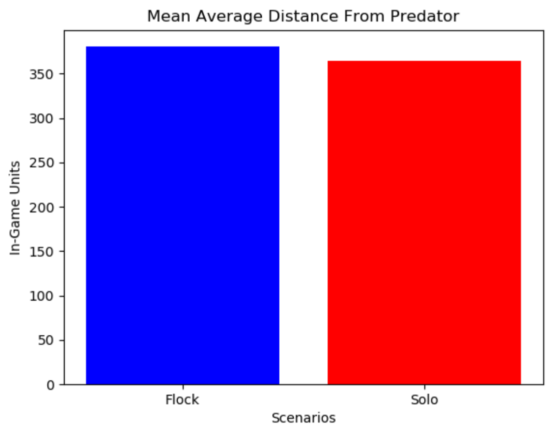
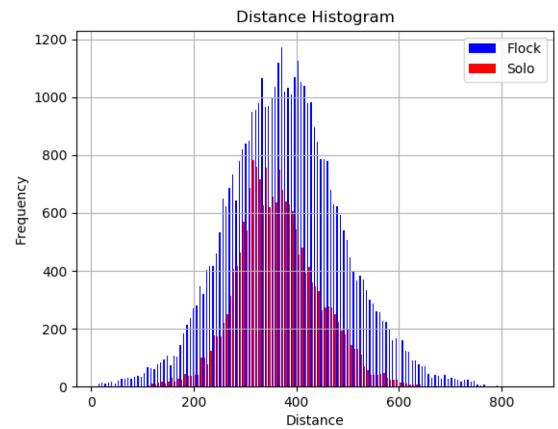
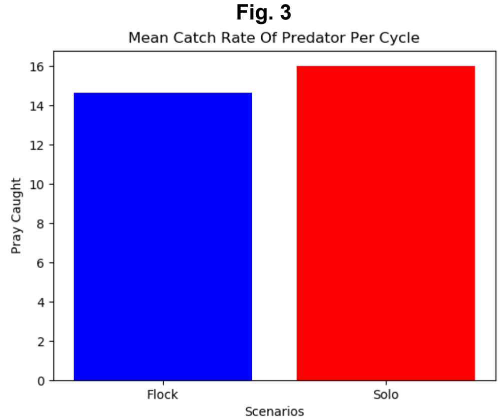


Fig. 2



Furthermore, the catch rates of prey in the flocking scenario were lower than those in the solo scenario(Fig.3). Lower catch rate might be attributed to less chaos in the simulation during the flocking scenario, in the solo scenario many more individuals were moving too slow and in the direction of the predator allowing it an easier opportunity to catch them.

Fig. 3



Additionally, survival time was significantly higher for the flocking scenario (flock mean survival time: 39.42) than those in the solo scenario (solo mean survival time: 17.89)(Fig.4). In the flocking scenario we also observed much higher maximum and minimum survival time(Fig.5) this difference in survival time might be attributed to the collective vigilance of the group which provides more opportunities for individual prey to evade capture.

Fig. 4

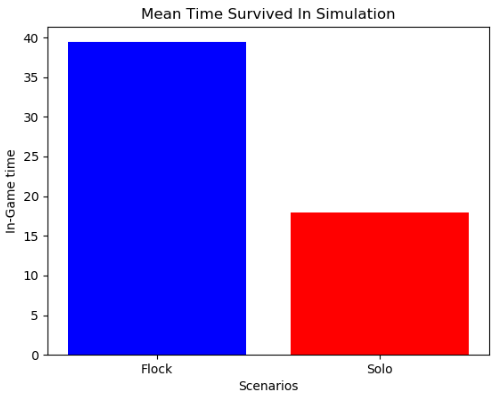
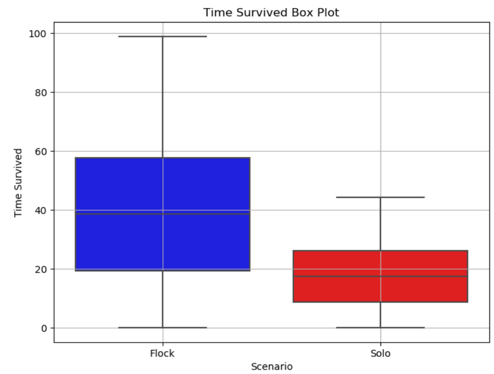


Fig. 5



Discussion:

The results of our simulation-based study provide strong evidence that flocking behavior plays a pivotal role in predator avoidance. The observed increase in average predator distance suggests that the collective movement of a flock serves as an effective deterrent to predators, limiting their ability to initiate successful attacks. The lower catch rates further support this notion, indicating that the coordinated movements of a flock can create confusion or difficulty for predators when selecting a target. The extended survival times of prey individuals in the flocking scenario emphasize the adaptive advantage of collective behaviors. By remaining vigilant and responsive to the movements of group members, prey individuals within a flock can evade predators more effectively than solitary individuals. Even in such a simple simulation we could still see some amazing emergent properties. We were able to observe Collective Vigilance when agents closer to the predator started moving away the ones further back were also moving away thanks to the alignment and cohesion of the group. Similarly we were able to observe Predator Saturation. When many agents moved at once near the predator it was hard for them to single out prey since the ones closest to them kept changing.
In conclusion, this study underscores the importance of collective behaviors, specifically flocking, in enhancing predator avoidance among prey individuals. Through emergent properties these complex systems allow for greater animal intelligence to be observed in groups of animals as opposed to when each one is separated. Future studies should focus on the optimal size of the flock which might help us better understand and thus preserve wildlife populations and hopefully lead to a more diverse and rich ecological environment.

References:

1. *Cresswell, W. (1994). Flocking is an effective anti-predation strategy in redshanks, Tringa totanus. Animal Behaviour, 47(2), 433–442. https://doi.org/10.1006/anbe.1994.1057*
2. *Reynolds, C. Flocks, herds and schools: A distributed behavioral model. Proceedings of the 14th annual conference on Computer graphics and interactive techniques - SIGGRAPH '87, 1987. [online] 21(4), pp.25–34. Available at: https://dl.acm.org/citation.cfm?id=37406*