How does the creation of co[redacted] predator clans with different parameters, as well as the implementation of flocking behavior in one o[illegible]he clans, affect the overall environment?

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Abstract

This paper explores the concept of collective intelligence by analyzing the collective behavior observed in a dynamic environment among foxes and rabbits. The study aims to understand the impact of introducing competing predator clans with different parameters and implementing flocking behavior in one of the clans on the overall environment. The research question asks how these implementations affect the ecosystem dynamics. The methodology involves the creation of predator clans, manipulation of movement behavior, and parameter modifications. The simulation includes predators, prey, and static agents. The results are measured and analyzed through population and prey consumption over time. The findings suggest that flocking behavior is not superior to random movement in this context, and certain parameters play a crucial role in predator-prey dynamics, particularly the sensing radius has a significant impact on survivability. Further research opportunities include exploring alternative movement patterns and expanding the simulation environment.

1 Introduction

This paper aims to analyze the concept of collective intelligence, focusing on the collective behavior observed in a dynamic environment among foxes and rabbits. Nature presents numerous instances of collective intelligence, such as the synchronized movements of bird flocks or the coordinated behavior of fish shoals. Communication within the latter group is facilitated through various signals, including sound, body gestures, and even color changes [1].

This simulation seeks to micro-model a population consisting of predators and prey, closely approximating the Lotka-Volterra model [2]. Our primary objective is to investigate the impact on the overall environment when introducing competing predator clans with distinct parameters, along with implementing flocking behavior within one of the clans. Thus, our research question is: How does the creation of competing predator clans with different parameters, as well as the implementation of flocking behavior in one of the clans, affect the overall environment?

To measure the outcomes of our simulations, we will use two main metrics. Firstly, we will utilize plots to visualize the changes in population over time, enabling us to understand the trends and dynamics of predator and prey populations. Additionally, we will generate plots to illustrate the average amount of prey consumed, providing insights into the feeding patterns and overall predation rates. These plots will take the average metrics of the simulations over 20 runs. To investigate our research question, we will conduct simulations in environments both with and without clans. This will be done to determine if a specific change would have any effect on either environment. There is an expectation that one clan might dominate the other, leading to the extinction of the other [3] We expect the experiments to have the following outcomes:

Movement-based experiment:

H_0a : The implementation of flocking behavior in agent Fox_2 will result in better performance compared to Fox_1 in both measurable average population and average prey eaten.

H_1a : Alternatively, Fox_1's random movement pattern in the current environment will result in better performance compared to Fox_2 in both measurable average population and average prey eaten.

Parameter-based experiment:

H_0b : The change of parameters such as increasing speed and reproduction rate will increase survivability for Fox_2 measured through the average population and average prey eaten.

H_1b : Alternatively, a bigger sensing radius will prove to be more vital for survival, making Fox_1 the dominant clan.

2 Methodology

To investigate our research question we will add three main implementations and compare their behavior in the environment. The comparison will be done by creating a simulation where the original predator will have to compete for survival against the new predators. We will call the different populations of predators clans. In the simulation, they will be distinguished by their color (white and blue). The differences in the clans that we will observe and compare will be that of the agents' movement, more specifically the extension of Flocking behavior onto Fox_2. Flocking is an individual movement behavior that consists of the agents adapting to the velocity, and position of their neighboring fellow agents [4]. To implement flocking for the investigation of H_0a we will be using the following three rules in our agent; alignment, cohesion, and separation. To investigate H_0b we will modify the parameters of agent Fox_2 with random movement. More specifically we will be modifying the speed, reproduction rate, and sensing radius.

There are three base agents in the simulation; rabbits acting as the prey, foxes as the predator, and grass as a static agent which the prey interacts with. Firstly, the static agent grass has two states "normal" and "eaten". It is initialized with no velocity and in the normal state meaning that it does not move. The color of the image used to showcase the agent aids in identifying which state the agent is currently in; "normal" being green and "eaten" being orange. For the agent to switch to the "eaten" state the Rabbit agent will need to perform the eat mechanic which is explained in the Rabbit section. After every update, the simulation will check if the grass agent's state is "eaten". After 150 updates the Grass agent will return to the "normal" state.

Non-static agents have a parameter that indicates stamina, this can be seen as a representation of the agent's life force or energy; the stamina of the agent will decrease by 1 at every update. If an agent's stamina was to reach 0 its state will change to "dead" and it will be removed from the simulation. Each agent will be initialized with a certain stamina value.

The rabbit agent has two states consisting of "alive" and "dead" (refer to appendix A for the full flowchart). The rabbit is initialized with a stamina of 750. While the agent is in the "alive" state the rabbit will act autonomously and have random movement. However, if the rabbit is in the proximity of the static agent grass and has less than 700 stamina, the rabbit will then eat the grass and gain 50 stamina. It is important to note that the grass can only be eaten if the static agent is in its "normal" state, otherwise, the rabbit will just continue its autonomous movement without being able to eat the grass.

As for the predator agent we implemented two different predators, Fox_1 and Fox_2 (refer to appendix B for the full flowchart). Both classes exhibit three states: "normal," "dead," and "ate." Both classes possess the parameter stamina which follows the same rules as for the Rabbit agent. It is initialized at 500. The predator agents are initialized in the "normal" state. The "normal" state of both classes is composed of three main components. Firstly, a check is performed to determine if the agent dies due to simulated natural causes, with the foxes having a 3% chance of mortality based on a PRNG system. The next component is a fighting mechanic between foxes from opposing clans. This happens when two foxes of opposing clans are in proximity to each other. At each update, a 25% chance of fighting is applied. In case of a fight, both foxes lose 10 stamina. Moreover, there is a 10% chance of the fight being lethal, resulting in a 50% chance of death for either fox. The surviving fox loses an additional 15 stamina. The final component in the "normal" state is the eating process. All rabbits within the fox's sensing radius are retrieved, and their distances to the fox are recorded, and stored in a list. The closest rabbit is then selected to enter the "dead" state, while the fox gains stamina and transitions to the "ate" state. In the "ate" state, a pregnancy stage is simulated, with the fox having to wait for 350 updates before reproducing. Once the reproduction has occurred the fox will return to the "normal" state.

Following the explanation of the main functioning of the fox agents, we can describe the differences between fox clans. Two experiments are conducted to evaluate the impact of movement rules and parameter variations. The first experiment replaces stochastic movement with movement rules, where both fox clans have the same parameters, but Fox_1 exhibits random movement, while Fox_2 adopts flocking movement rules. In the second experiment, both foxes exhibit random movement patterns, while parameters such as speed, sensing radius, and reproduction rate are adjusted for Fox_2 to assess the potential increase in survivability within the current environment.

To measure and analyze the full effect of these implementations separately and combined we will plot these results into graphs that show changes in the population over time as well as plots to show the average prey eaten by each predator. We will do simulations with and without competing clans, and see the average of the measurables over 20 runs.

3 Experiments

As stated at the start of the previous section we will be running experiments comparing the behavior of two competing predator clans with different qualities in an environment. In order for our experiments to have significance we first have to make sure that the different fox classes of agents are able to survive and reach a stable state when placed alone with the rabbits and grass in the environment. Therefore, in order to compare the performance of the foxes in our experiment, we used the behavior of the foxes with different qualities when placed with no competing clans as a control.

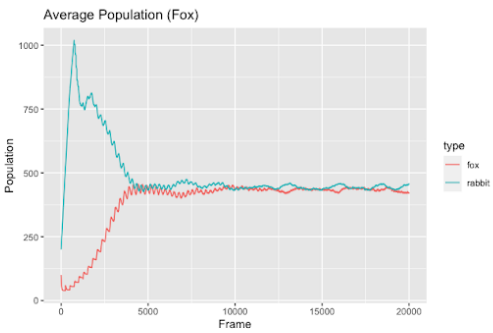

Figure 1: Average Population Fox_1 Alone

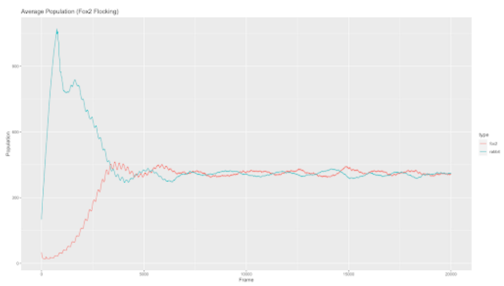

Figure 2: Average Population Fox_2 with Flocking Alone

These plots display the average fox (red) and rabbit (blue) populations over time. It can be clearly seen that after the first 3000-4000 frames the two populations reach a stable point where there are enough rabbits to feed the foxes but not too many foxes to cause the extinction of the rabbit population, and this continues until the end of the simulation. This allows us to see that by themselves, each different fox implementation is able to survive and thrive in the environment, and this will allow us to make comparisons later on in the results. We not only measured the average population of the simulations, but we also kept a record of how many preys were being eaten by the predators over time. This new metric also gives us insight into how the predators behave and how they interact with the environment and combined with the average population it will help explain the results in more detail. As the plots below show, not only do the average populations reach a stable state, but the average prey eaten also reaches a stable state.

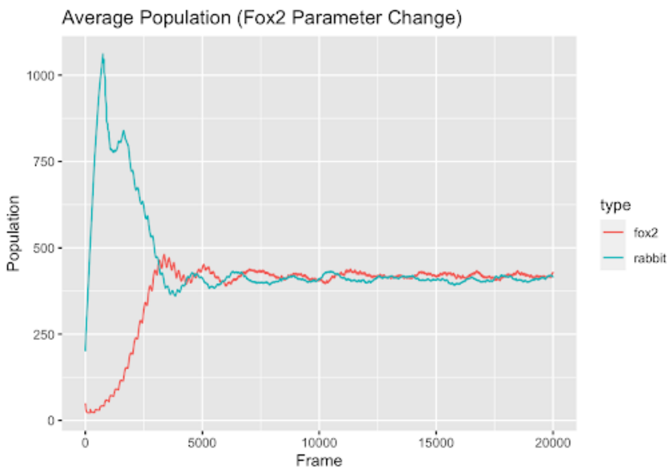

Figure 3: Average Population Fox_2 with Parameter Change Alone

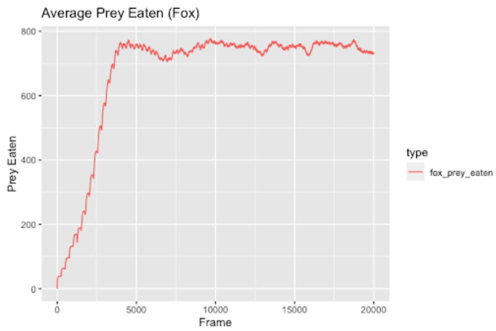

Figure 4: Average Prey Eaten Fox_1 Alone

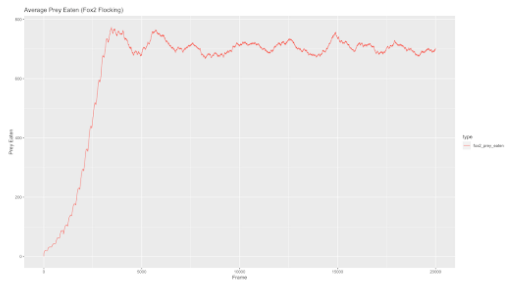

Figure 5: Average Prey Eaten Fox_2 with Flocking Alone

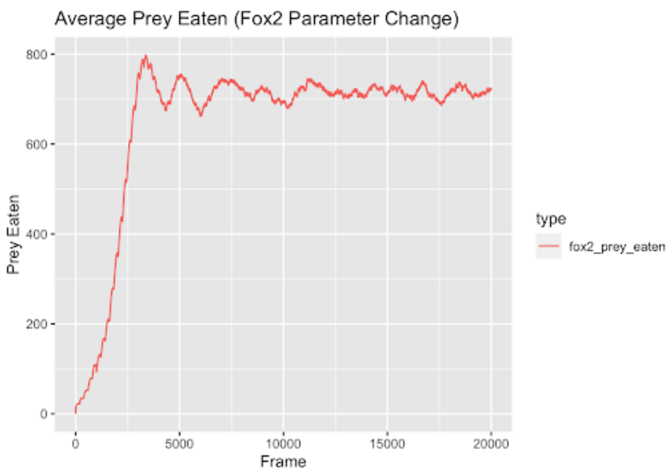

Figure 6: Average Prey Eaten Fox_2 with Parameter Change Alone

Now that we have discussed the results of the control tests and explained what they mean we can move on to discussing the results of the experiments themselves. The first experiment that will be discussed is the experiment in which we introduce flocking to the Fox_2 agents.

The plots display how the average population of both fox clans, as well as the rabbit population, change over time in Figure 7, and the average prey eaten by both fox clans in the same time

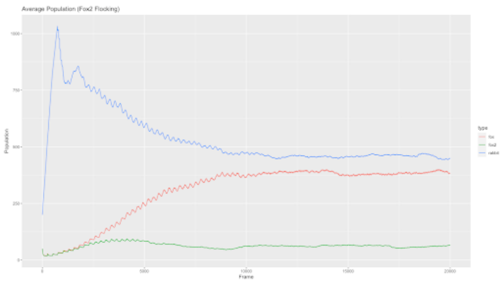

Figure 7: Average Population Experiment 1 Fox_2 Flocking

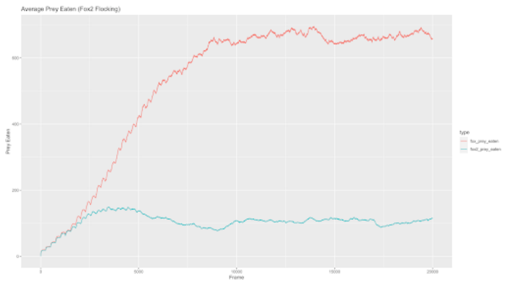

Figure 8: Average Prey Eaten Experiment 1 Fox_2 Flocking

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span. In the average prey-eaten plot we can see that Fox_1 (red) is eating much more prey than Fox_2 (blue), meaning that Fox_1 is better adapted to survive in this environment and therefore remains alive most of the time causing Fox_2 to go extinct in the majority of the simulations. This can be corroborated by the average population plot, in which the rabbit (blue) population reached a stable state around the same point as in the individual runs, however, we can see that Fox_1 (red) has a much higher average population than Fox_2 (green), meaning that most runs either Fox_1 was more prevalent or Fox_2 went completely extinct.

This may be explained by Figures 1 - 6 from the individual runs. We can see that on average, prey eaten by Fox_1 oscillated around 750 once the stable state was reached, while Fox_2 with flocking oscillated around 700. This difference however is not too large and there may be a different reason as to why this happened. A further inspection of the code revealed a possible reason for this in which the updates are calculated for Fox_1 agents before the Fox_2 agents, and due to Fox_2's behavior causing them to move close to each other could mean that a single Fox_1 agent, if lucky, could kill a group of Fox_2 completely on its own, meaning that Fox_2 would have a higher chance of going extinct.

Moving on to experiment 2, in which both clans have stochastic movement behavior but they have different parameters. The parameters that were tested were the following:

Parameters	Fox_1	Fox_2
Speed	1	1.25
Pregnancy Time (Updates)	350	200
Radius	25	15

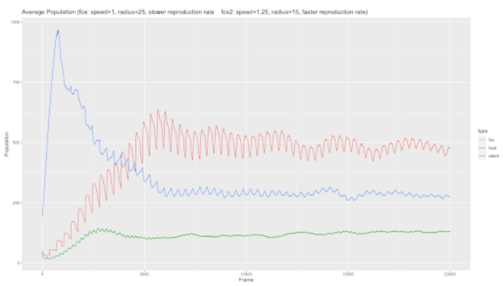


Figure 9: Average Population Experiment 1 Fox_2 Parameter Change

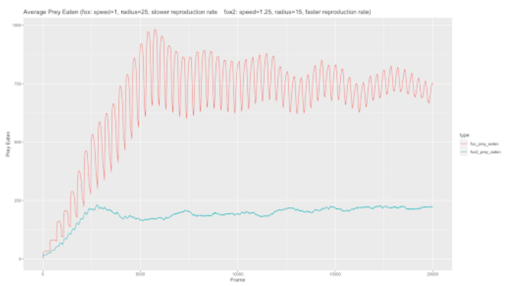


Figure 10: Average Prey Eaten Experiment 1 Fox_2 Parameter Change

For plots 9 and 10 we can see a similar result behavior-wise as in the first experiment, in which Fox_1 is more dominant than Fox_2 in both the average prey eaten plot, as well as in the average population plot. However, the plot for the average population has some differences, most notably the size of the average population. It can be noted that Fox_1 has a much higher average population once the stable state is reached than in the previous experiment, while the rabbit population has a lower average population than in the previous experiment. From this experiment, it can be concluded that the most significant factor for survivability in this current environment is the sensing radius. We can conclude this due to the fact that Fox_2 was faster and was able to reproduce at a faster rate, however, Fox_1 was still dominant. The reason for these results most probably is that due to Fox_1 having a larger sensing radius, it was able to find food more easily for the rabbits regardless of how fast they moved, and this allowed the population to thrive regardless of how slow they reproduced. This could also explain why the population of Fox_2 was higher than in the first experiment, as with a larger sensing radius it is easier to find food, even if it is more scarce.

4 Conclusion

The purpose of this research was to investigate the impact of flocking behavior and parameter changes on predator-prey ecosystems as modeled through the lens of the Lotka-Volterra model in agent-based simulations. To measure the effects, we monitored predator and prey populations, along with the count of prey consumed at each update/frame.

Contrary to our initial hypothesis H_0a that flocking behavior would prove superior to random movement, our findings revealed that Fox_2 the model using flocking behavior did not outperform the model Fox_1 with random movement. Similarly, H_0b was proven false and our results showed that H_1b was in fact accurate as Fox_1 outperformed Fox_2.

We faced several challenges during the course of our investigation, one being determining which parameters could be changed without compromising the integrity of the research. For example, when introducing competing predator species we would adjust the base wolf parameters to avoid species extinction. Striking a balance between the integrity of the research and accuracy proved to be time-intensive, as it required numerous iterations to identify an optimal combination of parameters. Next, analyzing the results led to us noticing a bug in the foxes fighting mechanic in which the chance of survival for Fox_2 was significantly lower than for Fox_1 due to the update order as aforementioned in our results section. This leads us to believe that more accurate results could have been obtained. We believe that with a larger time frame, we would be able to solidify the base fox agents parameters, as well as obtain more accurate results for our experiment.

Given the simulation environment for this project, we see many opportunities for future research. A practical next step could be exploring the impacts of alternative movement patterns in our agents, such as herding or schooling. On a more ambitious scale, the introduction of a weather cycle influencing both the environment and the agents promises an intriguing extension to our current study.

References

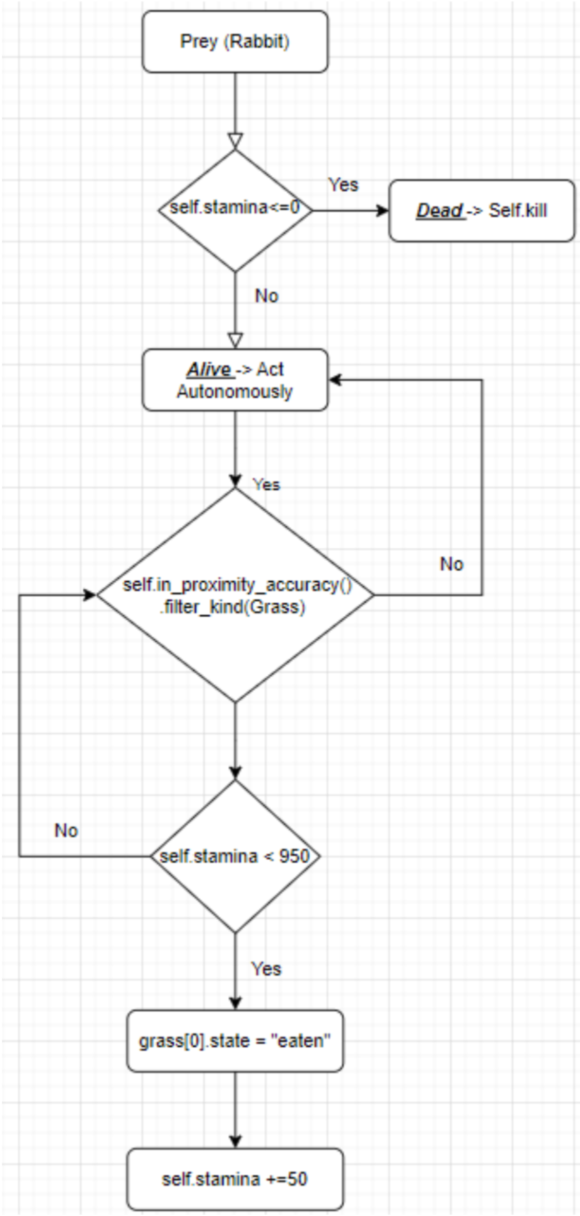
[1] Christos C Ioannou. Swarm intelligence in fish? the difficulty in demonstrating distributed and self-organised collective intelligence in (some) animal groups. *Behavioural processes*, 141, 2017.

[2] Mira-Cristiana Anisiu. Lotka, volterra and their model. *Didáctica mathematica*, 32(01), 2014.

[3] CJ Scogings and KA Hawick. Cross-caste communication in a multi-agent predator-prey model. In *Proc. Int. Conf. on Artificial Life and Applications (AIA 2011), Innsbruck, Austria, IASTED*, pages 163–170, 2011.

[4] John T Emlen. Flocking behavior in birds. *The Auk*, 69(2), 1952.

A Flowchart: Prey (Rabbit)



B Flowchart: Predator(Fox)