CIS559 Project 2 Organisms Final Report

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1. Insight, Observations, and Intuitions

At the beginning of the project, we ran multiple simulations to see how the provided Random Player performed under the default configuration. Our initial goal was to outperform the Random Player, so we want to identify its weaknesses and avoid replicating them in our implementation. During these simulations, we found that the default configuration had a spontaneous food appearance probability (***p***) of 0.01 and a food doubling probability (***q***) of 0.02 and from Figure 1,

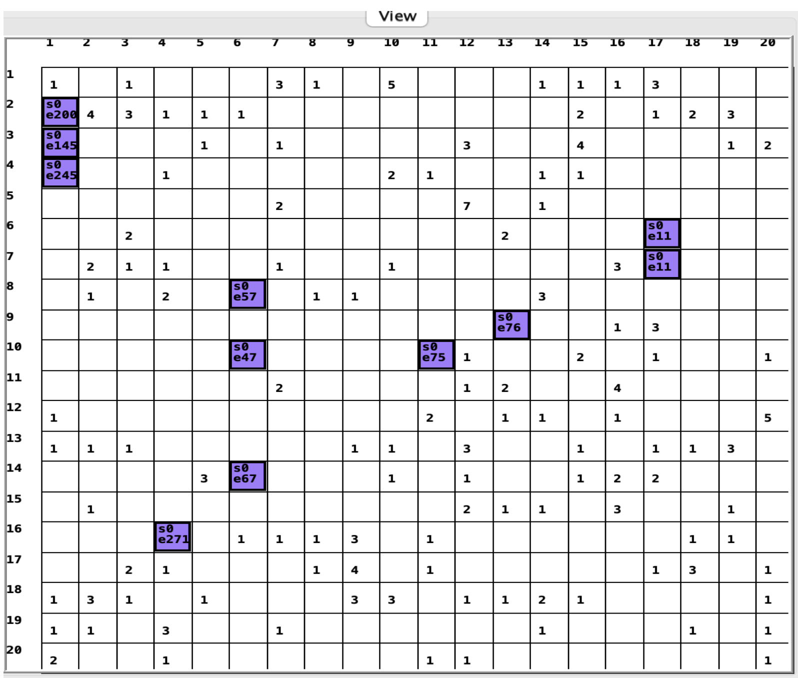


Figure 1: The distribution of food after 50 steps

We can observe that the default configuration creates a relatively abundant food environment for the player after 50 steps. After running the simulations numerous times and obtaining consistent results, we concluded that if an organism can survive the initial rounds (we set the threshold at 50 steps), it is very likely to survive till the end of game because of the relatively lush food condition. The main challenge is to ensure the organism's survival during the initial rounds when food distribution is sparse. Although the Random Player often survives after 5000 rounds, it usually becomes extinct when surrounded by little or no food at the initial rounds. This is because when surrounded by little or no food, the Random Player would randomly move around without finding food or eating food, consuming a significant amount of energy in the process. Additionally, since the Random Player makes decisions randomly, it might choose to reproduce even when energy levels are low. In a scarce food environment, reproducing at low energy levels accelerates extinction due to the reproduction costs. These factors are the main reasons for the frequent extinction of the Random Player.

After observing the behaviors of the Random Player, our initial intuition was to minimize unnecessary movements when food distribution is sparse so that we can reduce the amount of energy wasted. Although we lack the information about the precise distribution of food, organisms can "see" in the four orthogonal directions. Therefore, the organism is able to get the information of the neighboring cell and then we are able to make decisions based on the information of the surrounding cells. Moreover, in the default configuration, moving one step consumes 10 units of energy, while staying put only consumes 1 unit. This makes remaining stationary more energy-efficient when no food is nearby because in a sparse food environment, moving around can consume significant energy without finding food, accelerating the organism's extinction. Therefore, our strategy is to conserve energy by waiting for food to come within the organism's visible range and avoiding movements when no food is available and only reproducing when the energy left is abundant and there is food around.

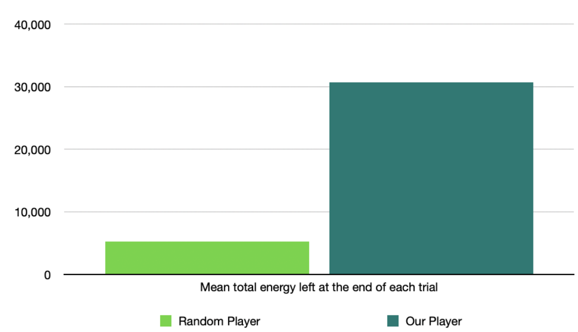
Using waiting as our dominant strategy, here is the pseudocode of our initial implementation details:

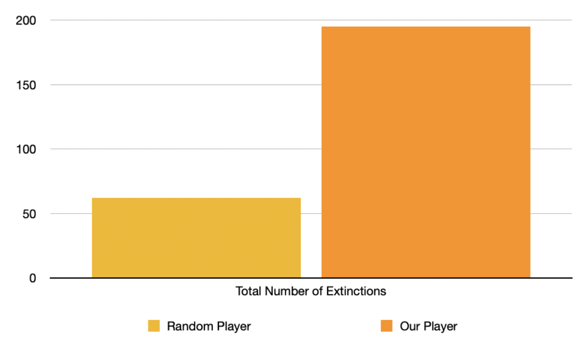
```
if there is food here and energy is less than max energy:
     stay put
if energy is greater than reproduction threshold:
     if there is food north and north is unoccupied:
          Reproduce and generate a child to the north
      if there is food east and east is unoccupied:
          Reproduce and generate a child to the east
     if there is food south and south is unoccupied:
          Reproduce and generate a child to the south
     if there is food west and west is unoccupied:
          Reproduce and generate a child to the west
if there is food north and north is unoccupied:
     move north
if there is food east and east is unoccupied:
     move east
if there is food south and south is unoccupied:
     move south
if there is food west and west is unoccupied:
      move west
stay put
```

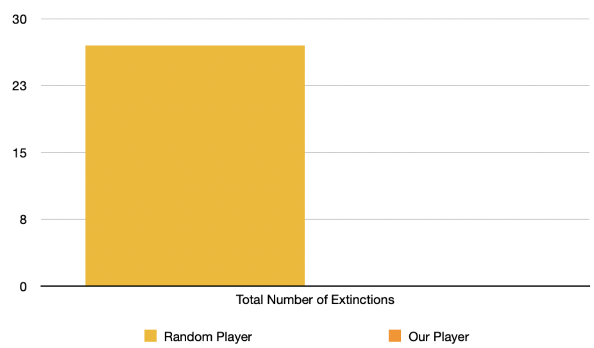
As shown in the pseudocode, the organism makes decisions based on its energy level and surrounding environment. Initially, if there is food at the current location and the organism's energy is not at maximum, it will choose to stay put to consume the food until it can no longer eat. Next, if the organism's energy exceeds the reproduction threshold(we set it to 250), it will check each of the four directions (north, east, south, west) to see if there is food and if the space is unoccupied. If these conditions are met, the organism will reproduce and generate a child in that direction. If reproduction doesn't occur because the organism’s energy level is below the reproduction threshold, it will then check again in the four directions for the presence of food and whether the space is unoccupied; if so, the organism will move in that direction. If none of these conditions are met, meaning no optimal movement or reproduction options are available, the organism will ultimately choose to stay put. By setting up these condition checks, we ensure that the organism does not move if there is no food around and does not reproduce if the energy level is below the predetermined threshold and there is no food available.

2. Limitations

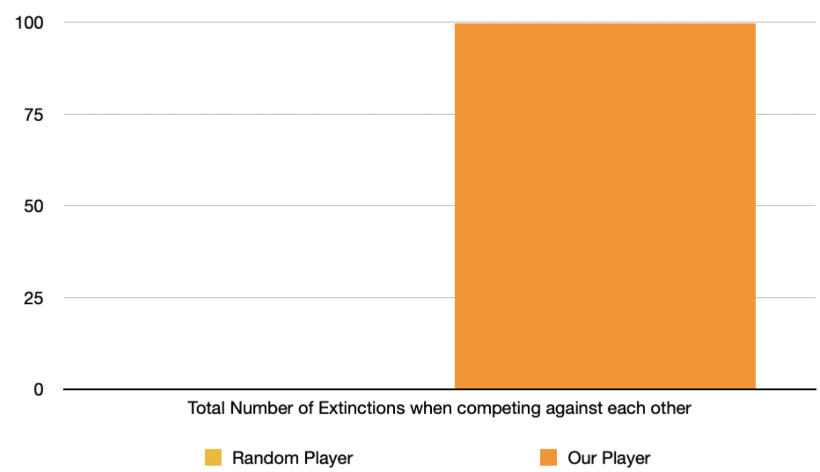
After running 100 separate trials with both the Random Player and our Player, the results demonstrated that our Player significantly outperformed the Random Player. The results are shown below:



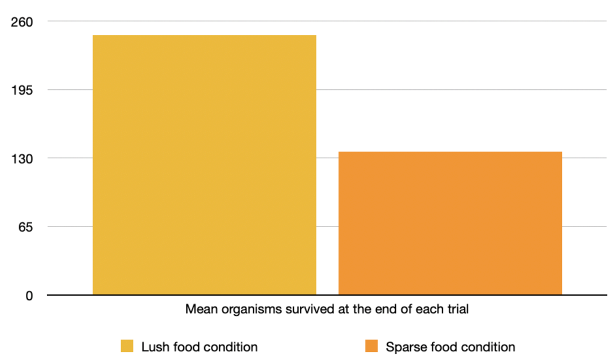


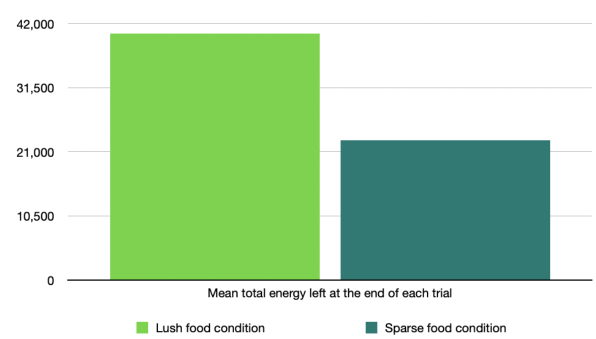


The figures above showed that the Random Player experienced extinction in 27 out of 100 trials, whereas our player had no extinctions in any of the 100 trials. This indicates that our player consistently survived until the end. In addition to improved resilience, our player also maintained higher energy levels and had more surviving organisms at the end of each trial on average. Here’s a refined version of your text with improvements in clarity and conciseness. We also conducted another set of 100 trials in which the two players competed against each other on the map. As shown in the figure below, our player consistently survived until the end at the end of each trial, causing the Random Player to go extinct at the end of each trial.



The results shown above demonstrated that our player consistently survived until the end of the simulation while outperforming the Random Player. Furthermore, in addition to the default food conditions, our player also performed well in both lush and sparse food conditions.

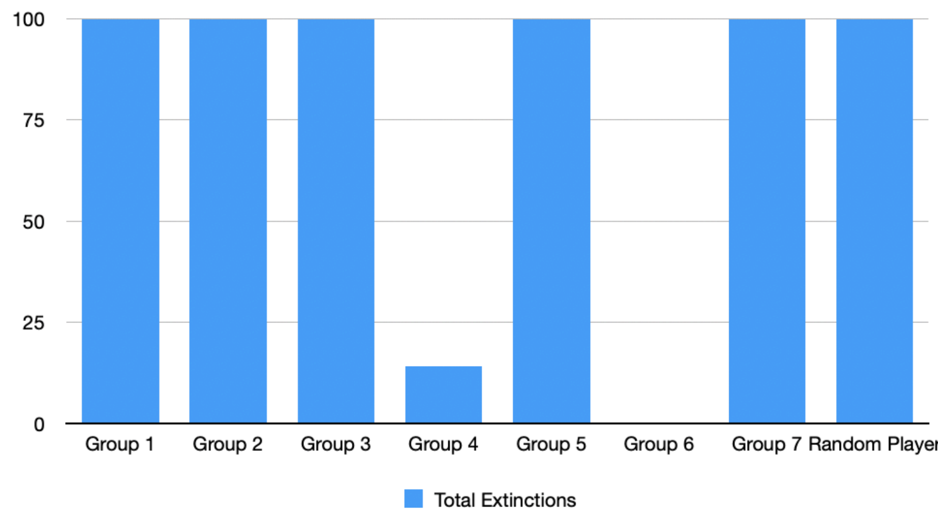




The results above show our player's performance across 100 trials in both sparse and lush food conditions. Our Player did not go extinct in any trials, regardless of the food condition. However, the performance was better in the lush food condition due to the greater availability of food. This abundance of food allowed organisms to reproduce more frequently and gain more energy, resulting in a higher average number of surviving organisms and total energy left at the end of each trial. The reason why it works for both lush and sparse food conditions is that the waiting strategy still works well. That is, Given that our organisms will reproduce when there is food around and the energy level is high, move when there is food around, and stay put otherwise, in the lush food condition, with the abundance of food, organisms have higher chances of achieving the reproduction threshold and thus reproduce more frequently. Even when the energy level is low, organisms also have higher chances of finding food and then move to the food and consume it. In sparse food conditions, although food supplies are limited, our organisms adapt by staying put to conserve energy. Staying put only consumes one unit of energy, allowing organisms to have enough energy to wait for food to come near. When food becomes available, the organisms move to it and consume it.

To conclude, in lush food conditions, organisms continuously reproduce and gain energy from abundant food sources, leading to the thriving of the species. In sparse food conditions, organisms remain stationary most of the time, allowing food distributed throughout the map to grow and accumulate. Once the organisms start to move or reproduce, the accumulated food from previous rounds has created a relatively lush food environment. In this scenario, organisms behave similarly to how they do in lush conditions, eventually reproducing continuously and gaining energy from the abundant food created by their initial stationary behavior, leading to the thriving of the species.

As we begin investigating the multi-species environment, we gradually discover several limitations in our initial implementation that lead to the eventual extinction of our organisms.



The figure above shows the total number of extinctions for each group, including the Random Player, when competing against each other in 100 trials. Except for our group(Group 4) and Group 6, all other groups went extinct at the end of each trial. However, our group still experienced 14 extinctions during the 100 trials. We observed that our player was too conservative to occupy more cells. That is, different from the one-player or two-player environment where we can always wait for food to approach us since there are a lot of cells and the accumulation of food during the wait would be enough to create a relatively lush food condition, the multiple-species environment presents a different challenge. In this scenario, competition for food becomes more intense, and waiting for food may lead to starvation or being outcompeted by other species. During the class presentation, Group 6 mentioned that they were inspired by our waiting strategy and incorporated it into their own implementations. However, they made their player more aggressive than ours. As observed from the simulation, Group 6's player continuously moves around for a certain number of steps. If they do not find food during this period, they then switch to waiting. This slight increase in aggressiveness leads to better performances in the multi-species environment. While using the waiting strategy can be effective, the added mobility allows their player to actively seek for food before resorting to waiting, which enables them to occupy more spaces and access possible food sources. That is, Group 6's player, by moving around more, can occupy more spaces, thereby preventing other groups, including ours, from moving or finding food, ultimately causing starvation or immobilization of the competing players. This explains why they can always survive until the end.

In conclusion, our player does very well in both lush and sparse food conditions and beats the Random Player consistently. However, in a multi-species environment, even though we can defeat most other groups, our conservative strategy can't overcome the other player who also uses waiting but is more aggressive. That aggressive player moves around more, takes up more space, and finds more food while still having a waiting strategy to conserve energy, which helps them survive in the end.

In our final implementation, we refined our strategy to make the player more aggressive while still retaining the waiting feature to conserve energy.

3. Final Implementation

We followed our intuition and observations above to come up with our final solution. All of our organisms follow the same set of rules, and we didn't use external states to make them behave differently. We split our approach into two main parts: one for handling situations where there is food nearby, and another for handling situations where there is no food around.

Here is the pseudocode for our final implementation when there is food nearby:

```
Food Around
    Energy > 60% Max
        Reproduce the Child in the food block
    Else
        Move to the available Food Block
        Reset alreadyMoved to 0
```

Explanations for our final implementation when there is food nearby:

Condition 1: If the organism's energy is more than 60% of the maximum energy, then the organism will reproduce the child in the block that has food. The 60% of the maximum energy was chosen by experimenting with different values. This condition comes from the intuition that when there is food nearby, we lower the energy needed for an organism to reproduce because the child will get energy from the food on its next move. This increases the possibility of survival of the child.

Condition 2: If the organism's energy is 60% or less, the organism will move towards the block that has food. After moving, set the "alreadyMoved" variable back to 0. This is used to keep track of whether the organism moved after it ate food, and we will apply this in the no food around section. This condition comes from the intuition that if the organism has a low energy, let it eat.

Here is the pseudocode for our final implementation when there is no food around:

```
No Food Around
    Food Here & eatable
        Stay
    no available block
        Stay
    Energy > 80% Max
        Reproduce the Child in the available  block
    Energy < One Move Energy * 4
        Stay
    Did not move since food
        Move to the available block
        alreadyMoved ++
```

Explanations for our final implementation when there is no food around:

Condition 1: If the organism is on a block with food and is still able to consume the food, it should stay on that block and eat the food. This condition comes from the intuition that the organism should do its best to gain more energy to improve its chances of survival.

Condition 2: If there are no available blocks nearby then the organism will stay. An available block is one that wasn't part of the organism's last 15 steps and isn't occupied by other organisms. The 15-step was chosen by experimenting with different values. We created an ArrayList to record the position of the organism's last 15 steps. Later we have condition 5 that will let the organism do some exploration, and we aim to make sure the organism does not explore repetitively.

Condition 3: If the organism's energy is more than 80% of the maximum energy, then the organism will reproduce and place its child in a random available block. The 80% of the maximum energy was chosen by experimenting with different values. This condition comes from the intuition that when there is no food nearby, we higher the energy needed for an organism to reproduce because the child is not guaranteed to get energy in the next move. We aim to make sure the child has a high initial energy to increase the possibility of survival.

Condition 4: If the organism's energy is less than four times the amount needed for one move, then the organism will stay to conserve energy. This condition comes from the intuition that when the organism is in a dangerous low energy state, the organism should stay to save energy to increase the possibility of survival.

Condition 5: If the organism hasn't moved since it last found food, then move to a random available block. After moving, increase the "alreadyMoved" counter by 1 to keep track of the organism's movement. This idea is contributed to other groups in the class. We add it to our implementation and it leads to better performance. It makes our organisms more aggressive, which is good when competing with other groups.

4. Analyze Algorithm Strengths and Weaknesses

When there is only one group of organisms on the map, our implementation can still be improved. Since there is no extinction in the single-group organism situation, we use the average count of organisms at the end of 5000 rounds in 10 trials to evaluate the performance of our final implementation. As shown in Figure 2, in all three maps, we're in the lower middle of the pack. This is mainly because of our conservative strategy: we had our organisms wait a lot and set a high threshold for reproduction. A possible solution for this would be to use the external state to check if there are other groups' organisms on the map. If there are none, we could apply a more aggressive strategy, which means moving more and reproducing more in the single-organism environment .

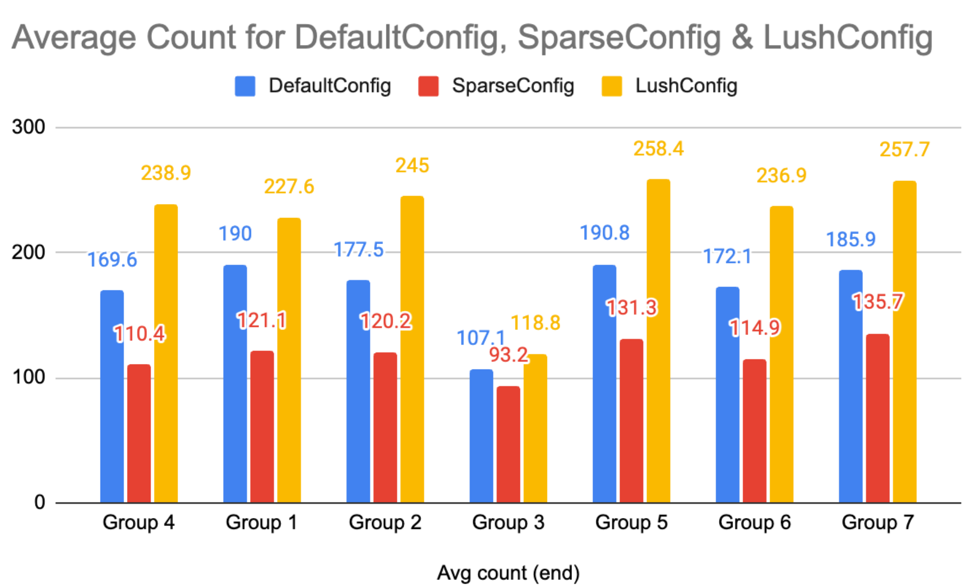


Figure 2

We ran 10 trials of our group competing against other groups in each configuration.When there are other species, survival rate is the most important indicator to evaluate the performance of the players. In Figure 3, we highlighted the situations where our group had more extinctions. As shown in Figure 3, when competing against other species, we have a fewer amount of extinctions. This result is expected because while still having a waiting strategy to conserve energy, which guarantees the ultimate survival in the end most of the time, our player moves around more, takes up more space, and finds more food.

However, we struggled in the Small Configuration when competing against 4 out of 6 groups because our strategy involves a lot of waiting and a high threshold for reproducing. On a small map, when we are competing against a more aggressive player, we might eventually go extinct. That is, in a small map, more aggressive players can quickly find food and occupy blocks through constant movement and reproduction. By the time our organisms start to move and reproduce, the other players have already occupied much of the available space and resources. As a result, our players often end up being surrounded and squeezed by other species, leaving them with no choice but to stay put and eventually go extinct due to lack of space and food.

	DefaultConfig	SparseConfig	LushConfig	SmallConfig	LargeConfig
Group 4	0	1	0	5	0
Group 1	7	8	2	2	3

	DefaultConfig	SparseConfig	LushConfig	SmallConfig	LargeConfig
Group 4	2	3	1	8	0
Group 2	3	2	0	1	0

	DefaultConfig	SparseConfig	LushConfig	SmallConfig	LargeConfig
Group 4	0	3	0	0	0
Group 3	0	4	0	0	0

	DefaultConfig	SparseConfig	LushConfig	SmallConfig	LargeConfig
Group 4	0	1	2	7	0
Group 5	0	7	2	1	0

	DefaultConfig	SparseConfig	LushConfig	SmallConfig	LargeConfig
Group 4	0	2	1	1	0
Group 6	4	6	3	6	0

	DefaultConfig	SparseConfig	LushConfig	SmallConfig	LargeConfig
Group 4	0	1	0	4	0
Group 7	7	9	4	3	0

Figure 3

When all 7 groups of organisms are on the map, our group performs quite well. With all 7 groups competing, survival becomes the most crucial factor, so we use the number of extinctions in 10 trials to evaluate our performance. Our player performed the best in the sparse food condition, as shown in Figure 4, where we had only 3 extinctions, tying for first place with Group 3. This success is attributed to our conservative strategy. When there's limited food on the map, excessive movement and reproduction can lead to extinction. Thus, our waiting and energy conservation strategy worked as expected

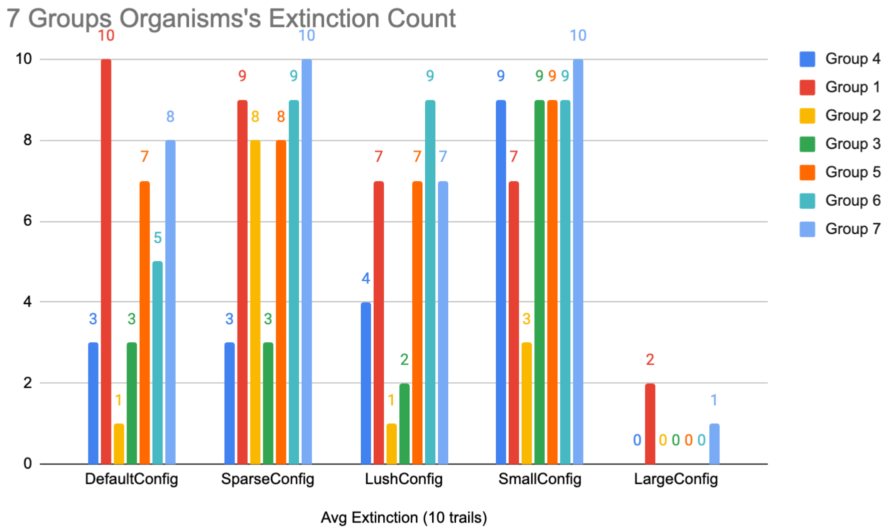


Figure 4

However, our conservative strategy is a double-edged sword, as it might accelerate extinction in certain situations. As shown in Figure 4, our player performs poorly in the Small Configuration when there are 7 species, with 9 extinctions out of 10 trials. The reasoning is the same as in the two-player case. That is, on a small map, more aggressive players can quickly find food and occupy blocks through constant movement and reproduction. By the time our organisms start to move and reproduce, the other players have already occupied much of the available space and resources, leaving our player with no choice but to stay put and eventually go extinct due to a lack of space and food.

As shown below, Figure 5 depicts 100 rounds of the game, where we are represented by the darker pink group with only 3 organisms on the map, which is fewer than most groups. In Figure 6, after 2000 rounds, we have only 2 organisms left, while the blue team and light pink team have dominated the game. This shows how our conservative strategy can lead to our organisms being outcompeted on a small map, as they are unable to secure enough space and resources to thrive.

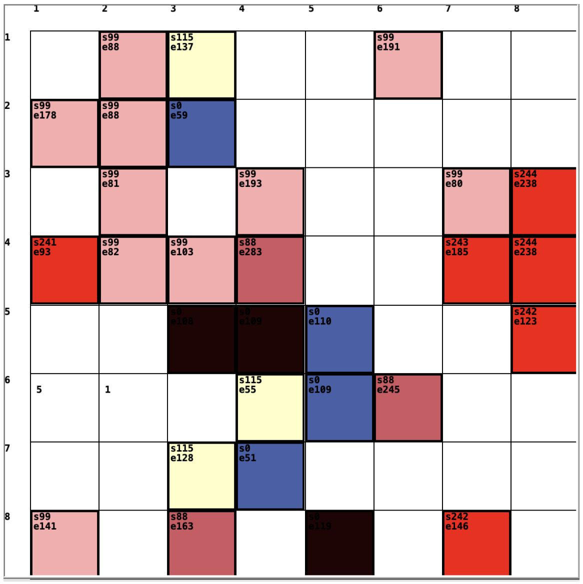


Figure 5

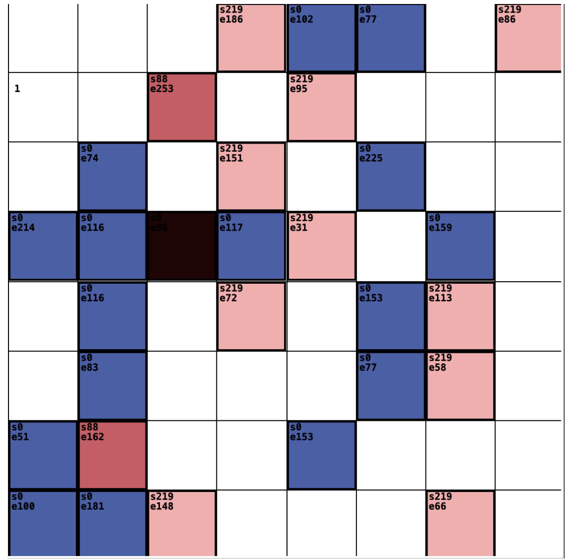


Figure 6

For the Default and Lush Configurations, we performed well, finishing second in the Default Configuration and third in the Lush Configuration. In the Large Configuration, most groups coexisted peacefully, and we didn't experience any extinctions because of the abundance of food and living space.

In conclusion, our strategy has several strengths. Our organisms performed well in sparse food conditions as a result of our conservative approach that emphasizes energy conservation and cautious reproduction. This strategy also proved effective in the Default and Lush Configurations, where we secured second and third places, respectively. Additionally, in the Large Configuration, our organisms coexisted peacefully with other species (with no extinctions) since in the Large configuration we have abundant food and spaces to thrive. However, int terms of limitations, our player does not perform well in the Small Configuration due to the overly conservative strategy. This leads to our organisms being killed by more aggressive players who quickly occupy available space and resources, resulting in a high extinction rate.

For future improvements, we believe it is crucial to adapt our strategies based on the status of each individual organism. Specifically, we need to add more aggressiveness to the player. For example, we might introduce variables to track how long an organism has stayed put. If it has stayed put for a certain amount of time, we would then allow it to move. While this might not be the best solution, we will continue to refine our approach toward this direction. Moreover, we plan to develop methods that allow our organisms to better understand the layout and food conditions of the map, enabling them to act more effectively in various environments.

5. Contributions

Our group's main contribution to the project was the idea of incorporating a waiting strategy into the player's behavior. This strategy involves the player conserving energy by staying put when food is scarce, rather than moving around in a fruitless search. The waiting strategy was inspired by observations that in certain environmental conditions, especially those with sparse food distribution, it is more efficient for organisms to stay put and wait for food to come within reach. This approach allows the player to conserve energy that would otherwise be wasted on unnecessary movement, thus increasing its chances of survival.

We noticed that other groups were always trying to move around at the beginning instead of waiting, which often led to quick energy consumption and higher extinction rates. By sharing our insights during class discussions and presentations, we helped other groups understand the benefits of energy conservation through strategic waiting. This was particularly useful for scenarios where food was not immediately available, as it allowed players to survive longer and make better use of the available resources.

We believe that many groups benefited from our ideas. Among them, Group 6 not only incorporated the waiting strategy but also made adjustments to ensure their organism's competitiveness in a multi-species environment. In the final implementations, we noticed that most other groups adopted variations of our waiting strategy, demonstrating its effectiveness. We are very pleased that our idea was recognized and adopted by our classmates.

6. Acknowledgements

During the lecture, every group presented the ideas of their implementation. We were surprised by the innovative ideas shared by our peers. Among them, we want to thank Group 6 for their inspiring ideas. Even though they used our waiting strategy, their improvement of moving around before waiting really enlightened us. It made us realize that our strategy was too conservative and could be more aggressive. Their innovative approach helped us improve our own implementation. We really appreciate their innovative thinking and the positive impact it had on our project. Moreover, we appreciated the joint efforts of us and Group 6 on utilizing the waiting strategy and improving upon it. This mutual exchange of ideas and collaboration helped both groups enhance their implementations and achieve better results.