Index

Introduction

Neuroeconomics is an interdisciplinary field that seeks to explain human decision-making, the ability to process multiple alternatives and to follow through on a plan of action. In the problem statement we tried to simulate and analyse the impact of small individuals on the population of the group.

We simulated a 2-D world where creatures called "Macpen" live. They rely on "canteen" for food which is required for survival and reproduction. On reaching a certain threshold, they reproduce by "fragmenting" themselves into two, and sharing the food equally. Also there is an entity called "ghost gang" which steals from the macpen. If the level of food falls below 0, then the macpan dies.

Three types of macpan exist:

1. Helpful
2. Ungrateful
3. Tit-for-tat

Case Study

Green=Helpful

Red=Unhelpful

Blue=Tit-for-tat

Default parameters:-

1.No. of macpan=3000

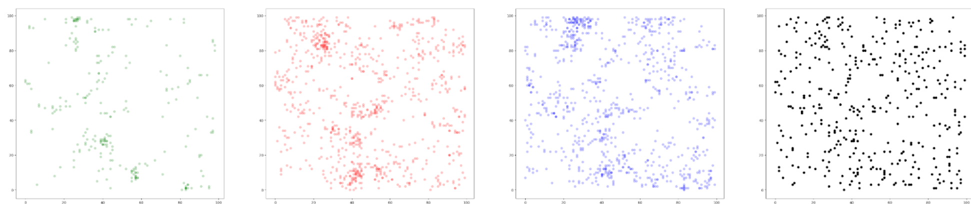
2.No. of canteen=400

3.Reproduction threshold=40

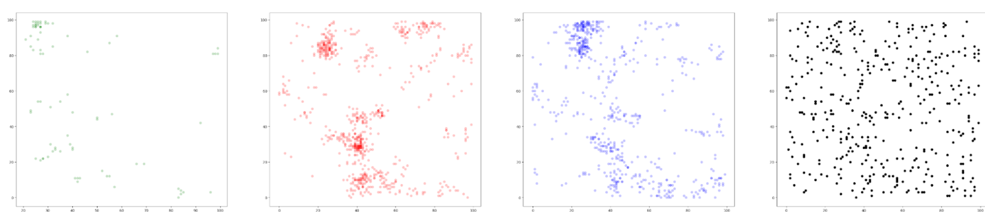
4.Dakku attack=20

6.Canteen Food=10

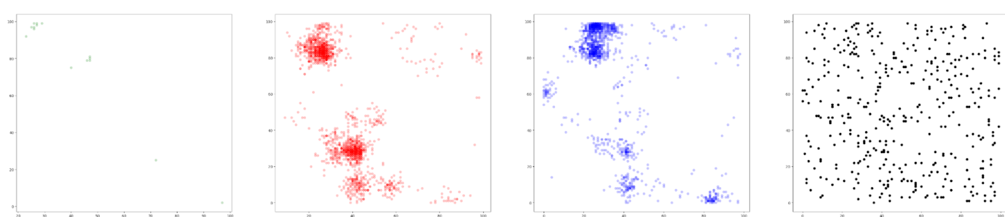
Simulation Results for default parameters:-



Day 0



Day 2



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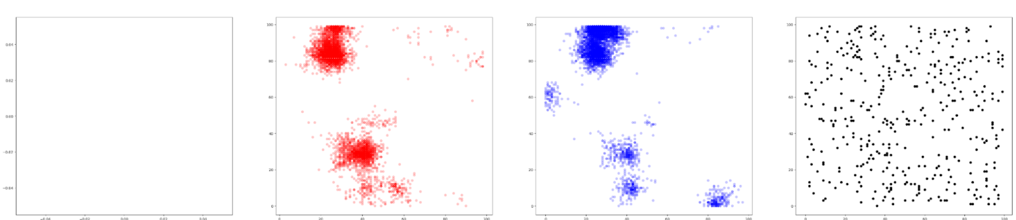
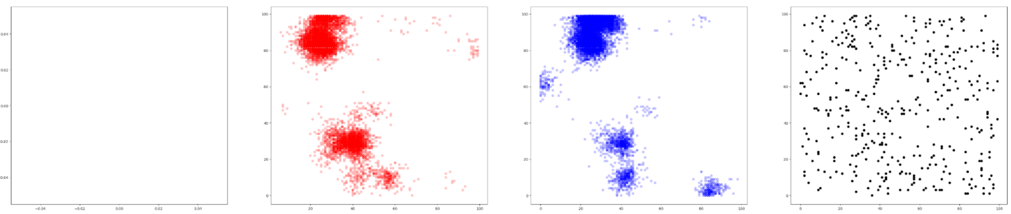
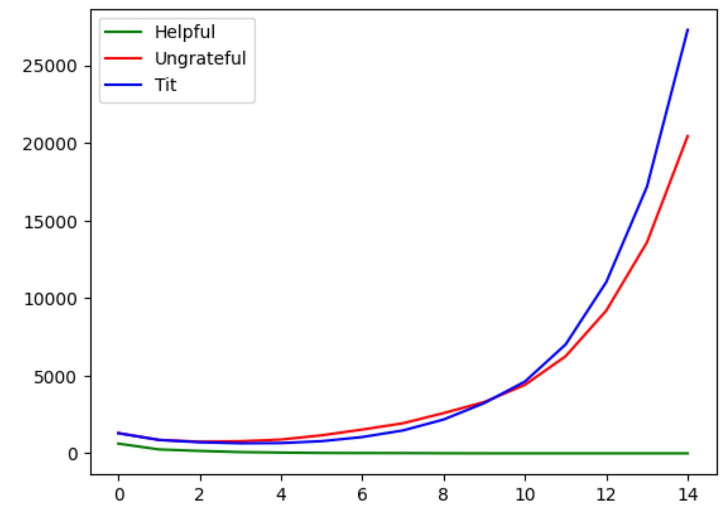


Day 8



Day 12

Line Graph:-



General consensus: The choice of default parameters was random. Upon observation, it can be pointed out that helpful is at a disadvantage in this situation and unhelpful and Tit-for-tat are in a close call. The clustering effects start with small helpful groups and unhelpful and tit-for-tat follow.

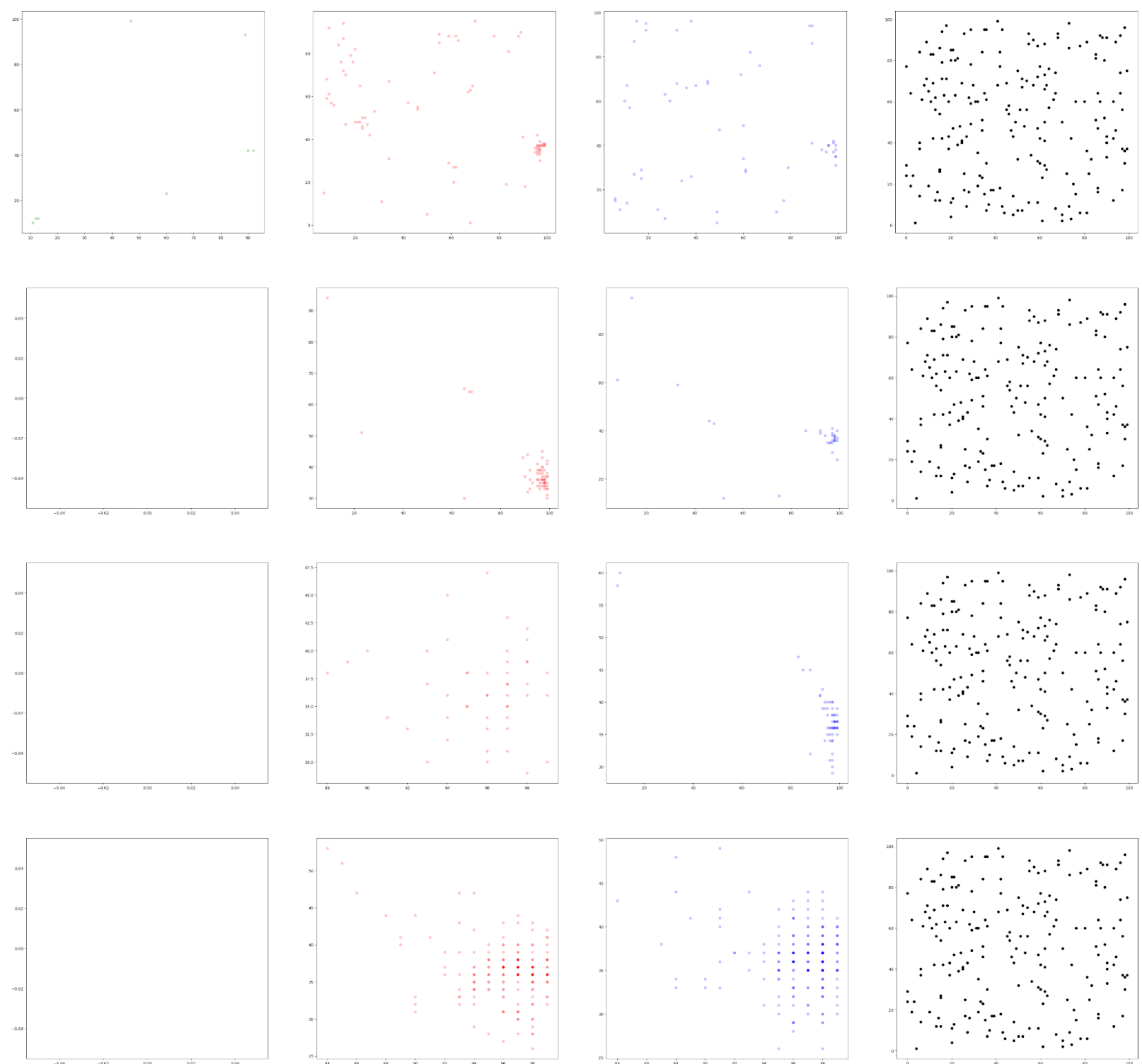
1.No of canteen : (200-600)

EXPECTATION

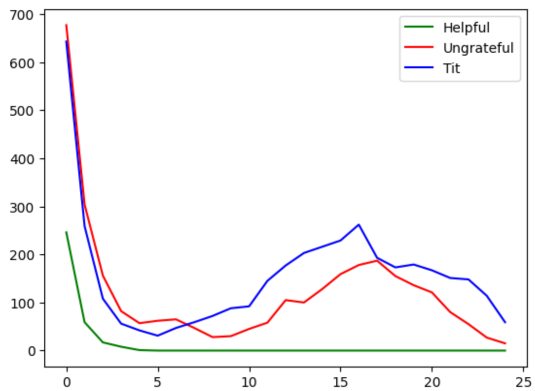
Here we expect that if we increase the number of canteens, the number of macpans should increase too because when we increase the number of canteens the food available to a macpan should increase that would result in better chance of reproduction for them similarly when we decrease the number the canteens we expect the total number of macpen should decrease as it would be difficult for them to get food and thus the Daku gang would kill them. Also it would be more difficult for them to reproduce.

RESULTS

We observe in the beginning that a small helpful cluster is formed ,around which an ungrateful cluster is formed with a very small cluster of Tit-for-tat. While clustering, the population of both ungrateful and Tit-for-Tat start increasing. Both ungrateful and tit-tat eventually kill off the helpful cluster by taking away its food and due to dense population and noone to give anymore food, their population starts decreasing and spreading away from the cluster to find food. Their population is on the decrease. Distribution graph:-

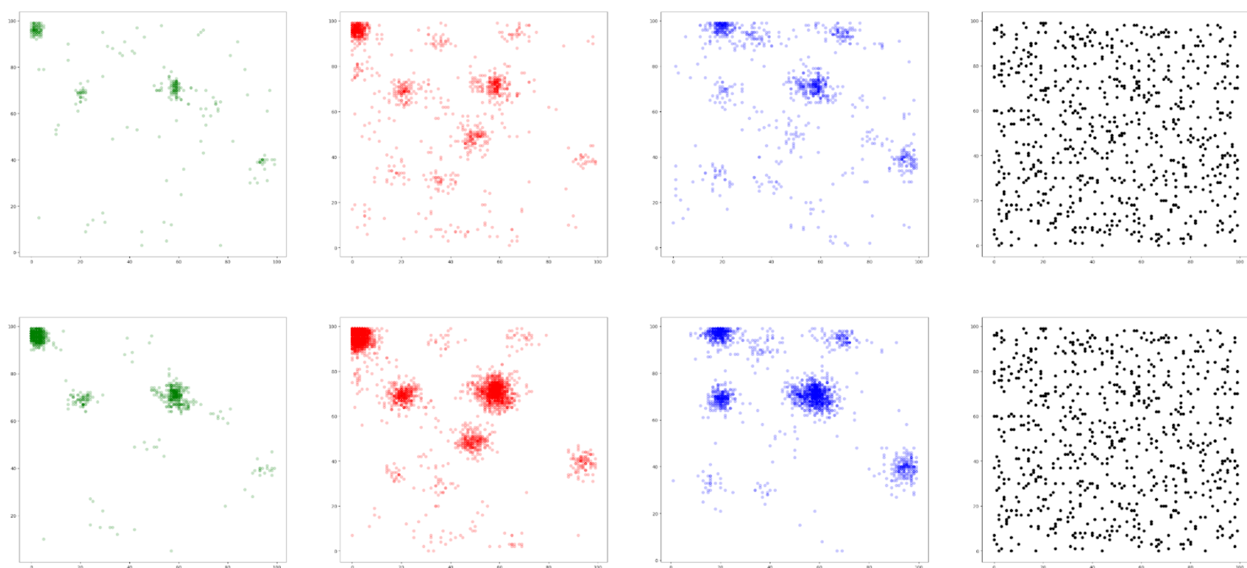


Line graph:-

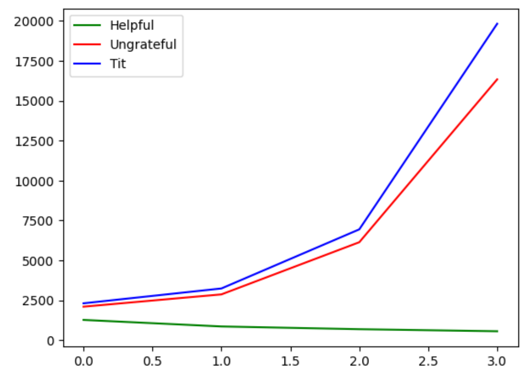


Now, when Canteen count is 600, like before, we can observe that due to the formation of the random initial cluster of the helpful macpen,the other macpen get clustered around it and try to kill it but this time as the canteen density was high, the helpful macpen survived and try to scatter but in the response of this the other macpen also start scattering . When we increase the no. of canteens this effect can be seen more easily.

Distribution graph:-



Line graph:-



2.Canteen Food(7-15)

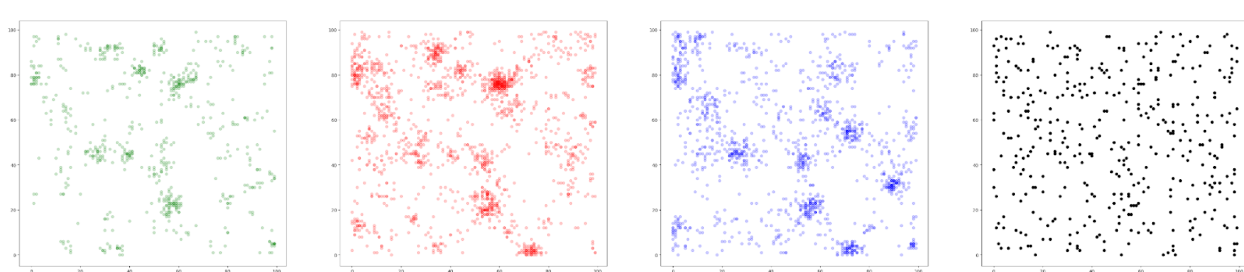
EXPECTATION

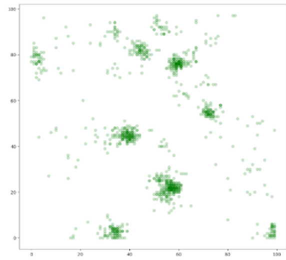
We now decided to play with the canteen food parameter. Upon increasing the canteen food quantum, we expect some sort of favorable change to our population as they are getting more food at every step where they encounter the canteen and thus reproduce faster.

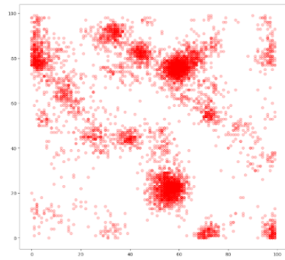
RESULTS

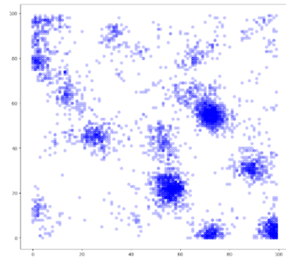
Upon running the simulation, we observe that canteen food increase leads to increase in population of all species initially and ungrateful and tit-for-tat clusters around the clusters of green and start killing them by taking away its food and disabling its reproduction. After a certain point, the increase in red and blue becomes tremendous which leads to a decrease in green. It can be seen faintly in the line graph that the green is stable while the other two are increasing extremely fast .

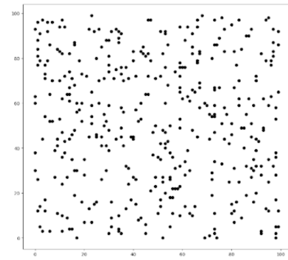
Distribution graph:-



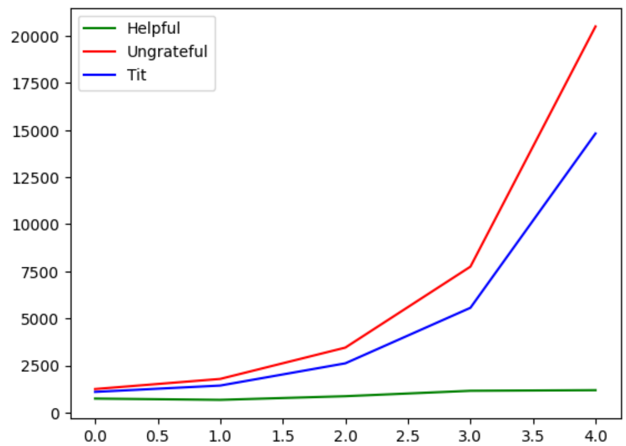








Line Graph:-



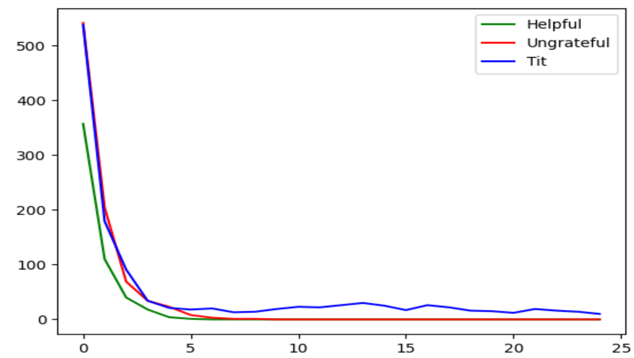
EXPECTATION

Now, we decide to decrease the canteen food level from default value of 10 to 7. We expected a decrease in population growth rate which may not be too visible as food received from the canteen at every step is just a little smaller.

RESULTS

But upon running the simulation, we observed that the mere decrease of canteen food from 10 to 7 leads to a tremendous decrease in population.This happens because the extreme scarcity of food due to which the number of macpen almost became 0 by day 2. This decrease can be seen evidently in the graph. A further decrease of canteen food level to 5 just exaggerates the effect.

Line Graph:-



3.Daaku Food deduction(15-25)

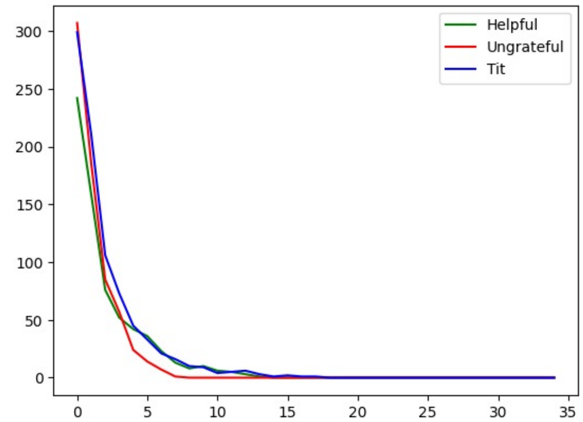
EXPECTATION

We now try changing the amount of food deducted per day from the default value of 20. We at first try increasing this value from 20 to 25. We expect a decrease in the population change rate from normal as the amount of food deducted increases, but this change is not expected to be tremendous as this increase is just 5 per day.

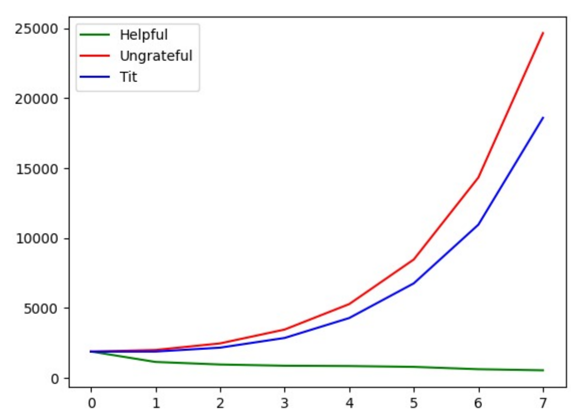
REALITY

Upon running the simulation, we notice that by a mere increase of 5 in the Daku coefficient from 20 to 25, no matter how much the reproduction is increased, death is almost always imminent. We did increase the reproduction threshold from 40 to 60 hoping it would compensate for this reduction effect by increasing the food collection of all species to a higher maximum and delaying its reduction by reproduction. Unfortunately, our prediction was proved otherwise.

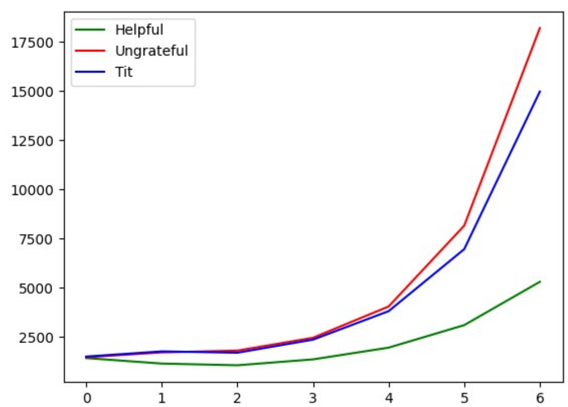
Line graph:-



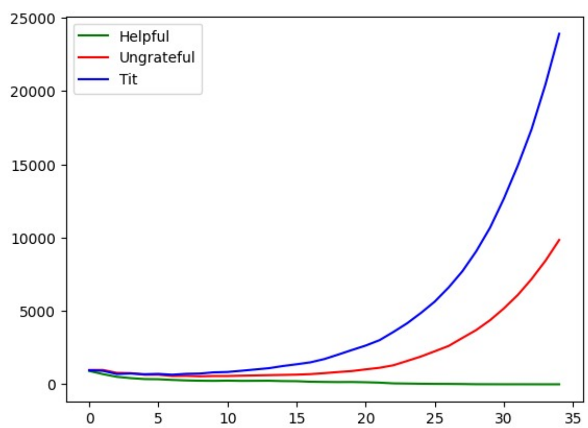
The scatterplot for the same starts showing signs of extinction by day 2 itself.
Now we decrease the amount of food taken by Daku gang to 15. This decrease favors the process of reproduction. It depicts a standard increase process where a certain cluster of helpful slowly increases to a decent size and then it starts getting surrounded by unhelpful and tit for tat. They enable a decreasing trend in the population of helpful and by themselves increase in size by increasing clusters. We further changed the reproduction level to check if the creatures would gather more food and survive even longer with a certain disadvantage at number as they reproduce less but this kind of an effect is visible only for helpful ones. We see that for Reproduction threshold 30, helpful starts decreasing eventually, which is due to its continuous reproduction. At reproduction threshold of 60, we see the same for helpful as it reproduces less and its clusters are being annihilateD by the rest. At 40 though, it has reached a level where these two effects have nullified each other and helpful has a tendency of increasing. The unhelpful and grateful always increase.
Line Graph:-



This is for reproduction level=30.

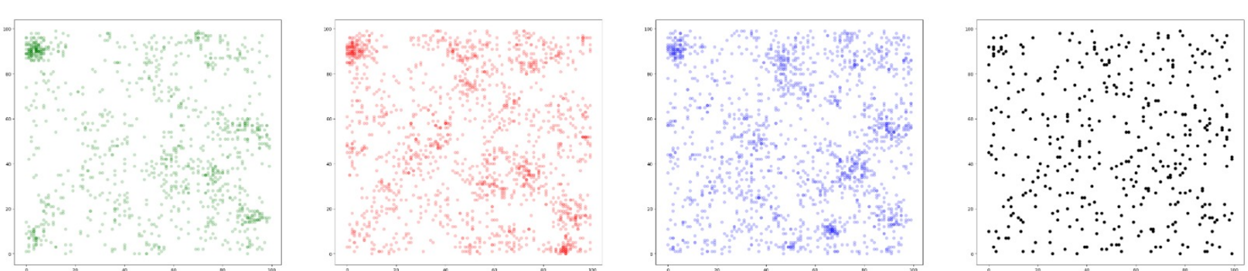


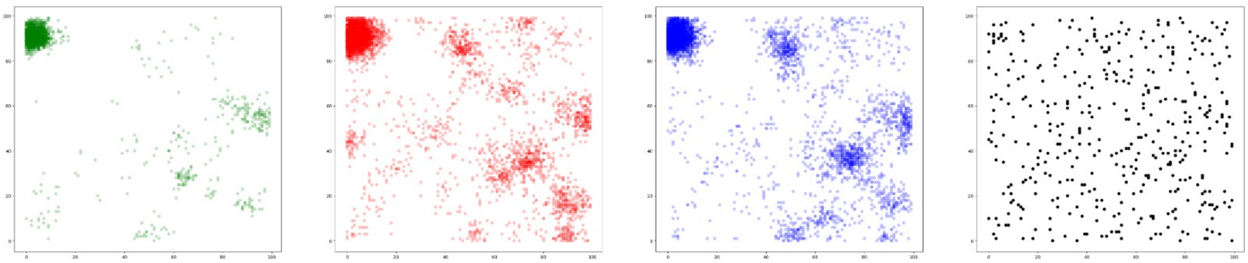
This is for reproduction level 40.



This is for a reproduction level of 60.

The general clustering pattern-





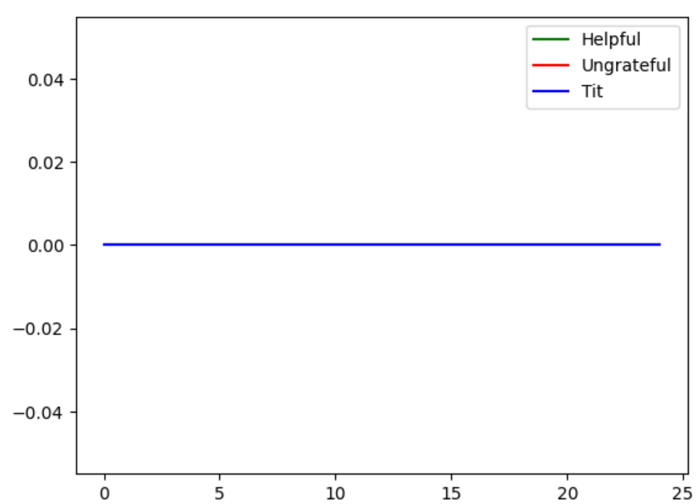
4. Reproduction Threshold:(20-60)

EXPECTATION

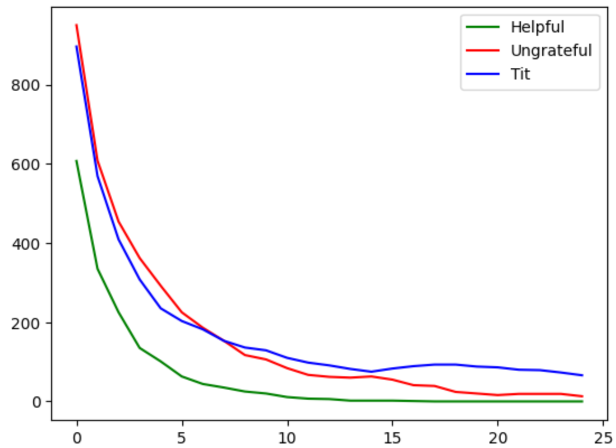
We now try manipulating the reproduction level solely to observe some changes. At first, we decreased the reproduction level to 20 and predicted that the macpen would reproduce at a very fast rate as their initial value of food is 15. This would lead to immediate death of all genomes as ghost attack itself is just 20.

REALITY

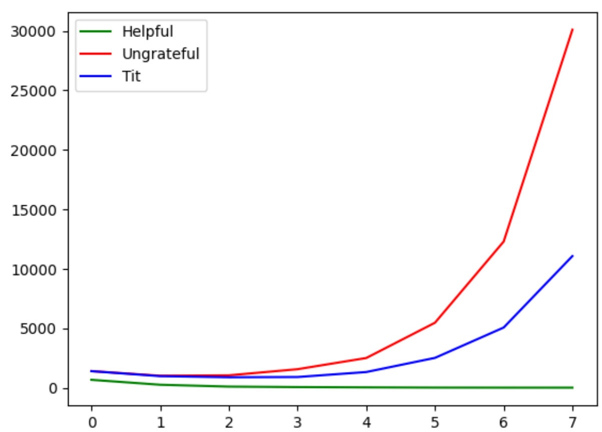
Upon running the simulation, we get the results that are coherent with these predictions. All the species die by day 1 itself and the graph is just completely flat for all.



Now we increase the reproduction level to 60. Upon this increase, we expect the species to survive for a longer period of time but population to decrease faster as species are in general accumulating more food but they are not reproducing and so some of them die out but some of them will get trapped in the cycle of gathering food and giving it to Daku gang. This prediction of ours matches with the actual simulation and population of every species decreases but doesn't exactly become zero.

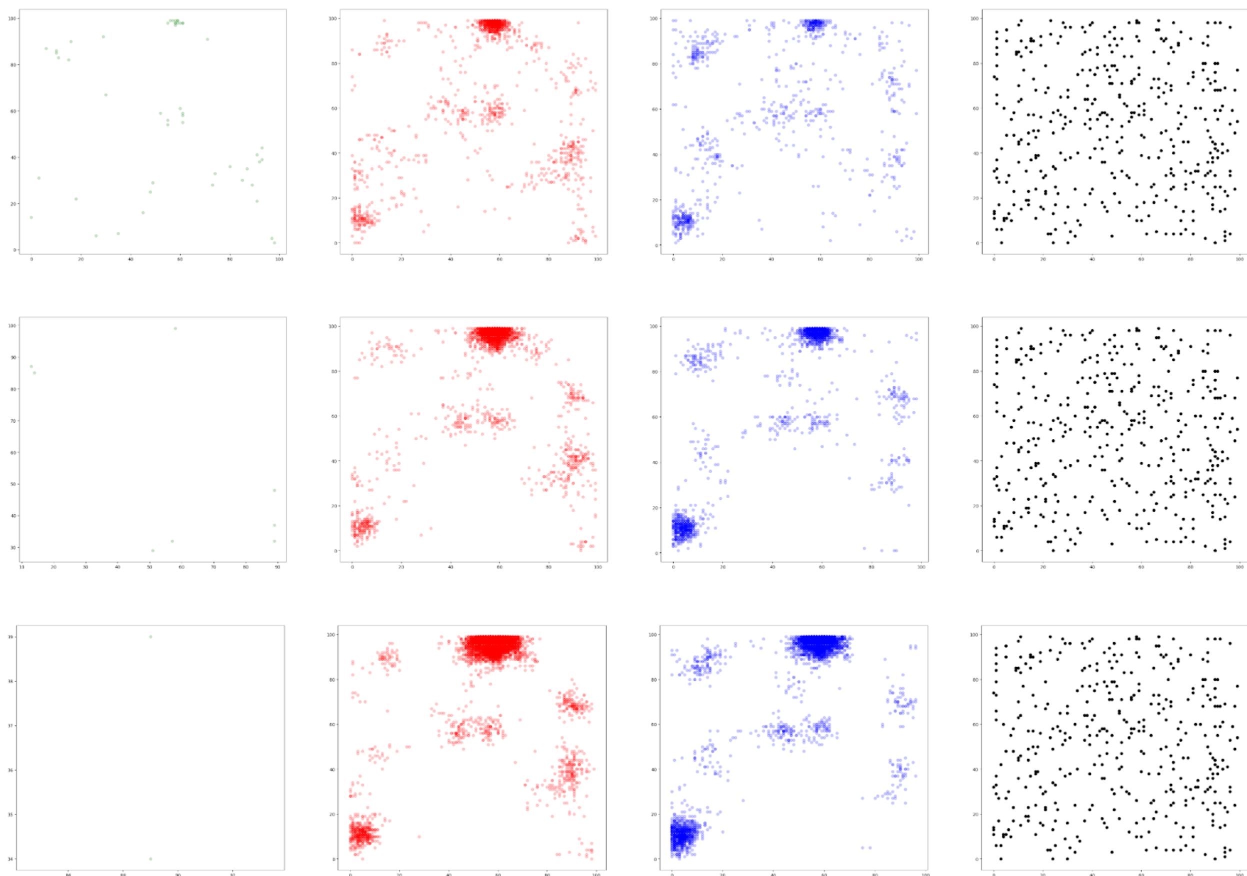


Now, when reproduction level is 40, this particular vicious cycle has a narrower bandwidth and the species doesnt exactly die out, as they reproduce with appropriate vigour and collect food fast enough for the increase of the species population over time.



We can observe over all the graphs that the helpful species is at a disadvantage. It is eminent enough from the spatial plots too. Whenever the helpful form a cluster, they start getting surrounded by both ungrateful and tit for tat as they are both being helped by the helpful without any bias. But this disables helpful to reproduce at all as they don't reach the food level required for the same and so, over time, due to Daku gang, they die out. Once they die out, the uhelpful and tit for tat behave in a similar manner indistinguishable from each other as both dont share with other species, tit for tat sharing among themselves only. This enables both of them to just collect food and reproduce and their population keep increasing with time.

The distribution graph for Reproduction level=40:



That for reproduction level of 60 is also same with the helpful dying out even quickly and then unhelpful and tit for tat slowly dying out to a very small population.

Assumptions

In order to produce a simulation, we needed to make certain assumptions:

- We take the canteens to be randomly fixed at the start of each simulation.

  It only makes sense that canteens are fixed at the beginning of the simulation for the entirety as these places being randomly generated after maybe everyday or time-step doesn't make sense. On top of that, since we introduced an intelligence movement, we wanted to expand our analysis if places of food sources were fixed.

- The macpen (tit-for-tats) can see the "genome", i.e., the "type" of other macpen.

  The only piece of information that can be made available is identification of a particular genome by the another through some kind of senses. Also, given the species remain the same, one can justify that these creatures, since its given interact with the next person differently given their genome, they somehow have to perceive what this genome is.

- The macpen know they have to reproduce at a certain food threshold.

  It has been studied upon that under favourable conditions of environment, an individual capable of it, undergoes asexual reproduction e.g. amoeba. We can correlate this idea with the fact that having enough food is a mark of favorability which makes an individual reproduce. This kind of information, accumulates in the individual's DNA via evolution and thus passed down from one generation to next. So, the new children produced, will also have the idea of this threshold.

- The Ghost gang attacks only at the end of the day.

  It can be encompassed under the assumption that the predator comes out at night to attack the people as it may have some kind of an advantage in that time period, maybe because somehow the macpen are more susceptible.

- We assume 24 timesteps in a day. The macpen will be able to move 24 times a day.

  Since it hasn't been mentioned, we assume a macpan makes a move every hour of a 24 hour day.

- The Macpen can see each other's food levels.

  If a macpan has to share food with the other person when they have excess, they have to perceive what the next macpan's food level is, otherwise this relative "excess" cannot be determined. Moreover, if the help is provided to the ones who actually need it, it shall ensure the survival of species which puts forward the idea that macpen may have evolved this particular healthy trait.

Parameters

- Grid size: The size of the square grid world (= 100*100)
- Number of canteens(=400)
- Number of days(=25)
- Units of food provided by a canteen to one macpan(=10)
- Units of food deducted in a single Ghost Attack (=20)
- Units of food required for reproduction(=40)
- Number of macpen(=3000)
- Number of helpful(=1000)
- Number of ungrateful(=1000)
- Number of tit-for-tats(=1000)

Environment

The environment is simplistic with randomly placed canteens throughout the grid. Daku gang is implemented by decreasing the food of each macpan by a constant amount at the end of the day.

We are implementing the environment using a Grid class which is initialized with all the parameters we use to run our simulation. These are the methods of the Grid class listed below:

- **place_macpan() method:** places the macpen on the grid.
- **place_canteen() method:** places the canteens on the grid
- **ghost_attack() method:** implements the attack of the "daku gang"
- **sharing_grid() method:** implements sharing by iterating through every cell in the grid
  It's working strategy is discussed in the strategies section

- **reproduce() method:** if a macpen is above the reproduction threshold at the end of a timestep the reproduce() method is called, it creates a new macpen and divides the food in half between the 2.
- **movement_intel_food() method:** Implements movement, it's working strategy is discussed in the strategy section
- **canteen() method:** adds food to the macpan if they land on a canteen during a timestep

The macpen are also implemented using objects.

Strategies

- ***Movement strategies***

There is an intelligent movement implemented. The gist is that it goes on in the direction that has been favorable to the macpan. This means, it will probabilistically go in the direction in which the macpan has received most amount of food in the history.

This is implemented using the idea that average food received upon traversal in every direction during the history of Macpan is calculated and we use these averages to caculate the probabilities of selecting a direction. Negative averages are dealt using the exponential function.

- ***Sharing strategies***

We are trying to maximize the chances of survival so we ensure the sharing of food is in such a way that is mutually beneficial. The helpful will share only when it has more than 20 food, always ensuring that its own food supply does not dwindle below 20.

The agent with the least excess shares with the agent which requires the least to come above the threshold. The agent with the 2nd least excess shares will donate to the agent which requires the 2nd least to come above the threshold etc. This means the richer macpan will share more.

Tit-for-tat acts based on its history with the grid, i.e if it has received a lot of food it will be generous and share following the above strategy. If it ends up sharing more than it has received it will be ungrateful and will not share its food.

Summary

The idea generally expressed by all this analysis is that the intelligence in movement generates a tendency of formation of clusters around the helpful blobs for almost every case as it is the one that shares food to the blobs and thus its towards their direction that they will receive more food. Moreover, the helpful one is at disadvantage the most because it just gives away food to everyone else and unhelpful one is at the most advantage because it just receives and doesnt give away. Moreover, in an environment consisting just of Tit-for-tat and unhelpful, both act almost identically. We have also noticed that changing parameters doesn't change much for helpful macpen but do affect others.

Increase in the number of canteens increase the general population growth rate. Increase in the food given by canteens also makes the same change. Increase in reproduction threshold makes the survival of species more favorable rather than their number in the nature. Finally, the population is very sensitive to the number of food units taken by a ghost attack and its increase very much annihilates the population growth rate. All of these affects have been explained upon in the places where they have been altered

Bonus

We could have a similar environment with a new type of macpan, the cannibal. As the name suggests, this new type of agent will eat its own kind and other macpen in the same cell if its food level falls below the threshold.
This would have huge implications, especially in the early stages of the simulation.
We can replace tit-for-tat with cannibals and observe the dynamics of the simulation.
This could create very interesting situations like if a hungry cannibal stumbles onto the

edge of a cluster, it can rapidly eat and multiply completely changing the population statistics in a few days.
In the abundance of canteens this system would behave pretty similarly to our original system.
If there is a cluster of cannibals that grows too large without canteens nearby it would start consuming itself establishing a sort of equilibrium in it's population.

We might also observe a reflection of the real life oscillations in some predator-prey populations in our simulation. As the helpful and ungrateful population grows, They get consumed by cannibals. Then since the cannibals have less to eat their population reduces and the helpful and ungrateful population rises again and so on.

References

1. *Simulating Green Beard Altruism*, Primer (youtube channel) https://www.youtube.com/watch?v=goePYJ74Ydg
2. https://en.wikipedia.org/wiki/Green-beard_effect
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