Competition and Cooperation
an Agent Based Modelling perspective
CGS 702: Project Report

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Abstract

In this work, we are trying to investigate whether cooperation helps- that it has better outcomes for its higher levels than lower- by using the Agent Based Simulation paradigm. We explore that in a simulated dynamic world that's populated with agents who sustain by getting energy from a limited number of natural energy sources. The various world parameters contributing to cooperation and their effects are attempted to be formalised. Also, we have tried to come up with a very basic model of a competitive world.

1 Introduction

Motivation

Even though much of today's world and economy is driven by global interactions for moderately goals, we have also seen some major pushback from regional populism across the world wanting to secure and maximise their own benefits. Consequent repercussions can be seen in global trade, politics as well as important policy decision implementations like climate agreements. This inspired us to try to test for small-scale cooperative or competitive societies and whereon we can later build for more complex behaviors in more complex worlds.

Broad view

We will be looking into how lower or higher levels of cooperation and how changes within the parameters of cooperation has effects and outcomes on populations and social situations.

Basics

Cooperation is the basic sense of paying the cost for someone else to receive the benefit. The benefit can be in terms of reproduction (cultural or genetic), survival, growth of population.
The paper 'Factors involving Cooperation in Commons dilemmas' Shirley Kopelman et al[1] pointed to the various attributes affecting cooperation. From the decision structure and social structure paradigms that they analysed, we chose communication to be the key parameter of our protocol of cooperation.

Why communication as cooperation?

We understand that in a world which is constrained with resources, information about any potential resource is of the greatest value to any individual in the world. So if I get information about some resource in the world, then I will gain. And similarly if i give information, then the one who I communicate with, gains. And thus we use the communication of information as a proxy of cooperation and thus test for effects of variation of different levels of communication.

ABM

We need to somehow model the various interactions that may take place. But this cannot be easily experimented behaviorally because of all the variables involved that may render unpredictable effects in an emergent phenomenon, even in primitive level. Therefore, we model the world and agents using the Agent Based Modelling paradigm. And out of the near 89 listed ABM tools[2], we selected to use Mesa[3] because of its python-based viualisation-module enabled open-source nature,

2 The work

2.1 The designed world

2.1.1 Designed world components

Idea of the world is abstracted with agent-agent, agent-environment interaction in order to study processes, objects, events consisting of space where agents move around making decisions at every time step being activated randomly.
• The world is modelled as a 100x100 multi-grid (multi-occupancy). 1 cell being the unit of distance.
• The world has limited number of natural energy resources, each with starting energy content and depleting decay rate.
• Agents perform agent-agent, agent-environment interaction in complex manners for interesting collective behavioral patterns to emerge. 2 types of agents, EXPLOITERS (static population) and EXPLORERS (dynamic population).
• Living Cost: cost of moving as also cost of static living.
• Sense Range: radial distance for sensing resources. (more for explorers than exploiters)
• Communication Range: radial range withing which he can communicate
• Mining Rate: rate of obtaining energy from resources.
• Exploiters: Mostly static population who search for energy actively only when their own energy levels goes below a certain threshold or also move randomly otherwise with a very low probability. Higher living and mining costs.
• Explorers: The dynamic population find new energy initially starting off from a base location with random drift direction for each explorer. They return to a random position in base after fixed timesteps to communicate with other members. They've Lower moving costs and lower mining rates, and higher communication and sense range

2.1.2 Flow of world

• Spawned energy resources lessen with decay and consumption. If falls below threshold, it vanishes. If total energy from all the reserves fall below a certain threshold, energy source with that critical energy is added back.
• The agents are spawned in bounded base start off with energy randomised within a range. Explorers drift, return, drift again while exploiters settle to static life. If energy dips below threshold, the agent proactively searches for energy resource, scanning its own memory buer calculating the expected energy content of each resource at the expected time of arrival and thus epsilon-greedily selects and goes to the best resource.
• Explorers can borrow energy from exploiters with some low probability.
• Population grows as agents asexually reproduce when above a certain threshold spending a large amount of energy
• information of all known resources– time of sight, capacity, location, decay-rate– maintained in agent memory is used to calculate expected content of energy resources while optimising which one to go to.
• Agents share some information with some of the people it can communicate with in its communication range.

3 Our investigations with the world

We understand that communication in the societies in our world thus becomes driven by three factor-step process:
• other agent should be within the communication range of the communicating agent
• probability that the communicating agent communicates with the agent-in-range of self or other type
• then there is the memory sharing probability with which each block within the communicator's memory gets added
Upon these factors we build and test cooperating and competing society test conditions.

3.1 For cooperation

Main independent parameters used as cooperation:

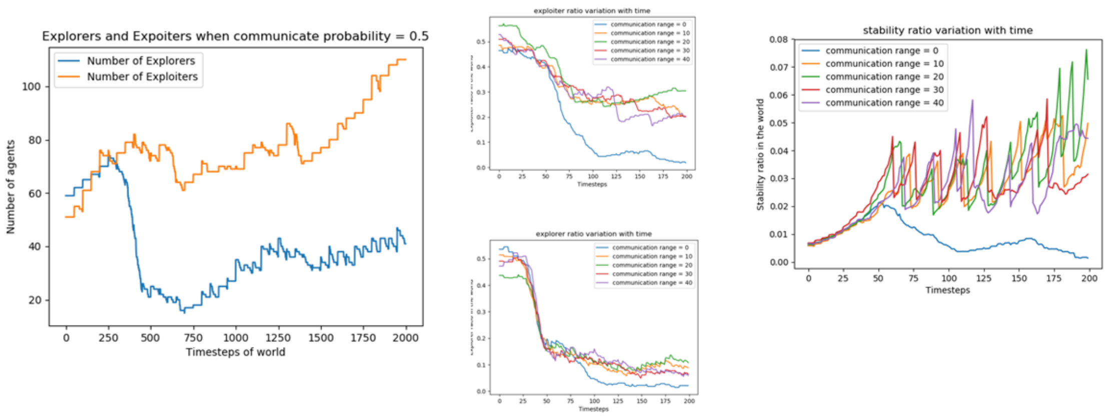
1. Communication Range (max range within which agent assigns neighbours that it will communicate with)
2. Communication probability (INTRA and INTER for Explorers Exploiters for within group as well as outside of it)
3. Memory Sharing (proportion of information in memory over random uniform function it will share with neighbours)
We will test effects for these parameters independently as well as look at how they affect the outcome when working in tandem under the umbrella of a 'Communication Level'.

The dependent parameter for cooperation:

Since any cooperation should hypothetically have positive effects on fitness, we decide to test on variation of the age of the population as well as the size of the population, and taking it under their multiplicative form - 'Output' or 'Fitness'.

Results

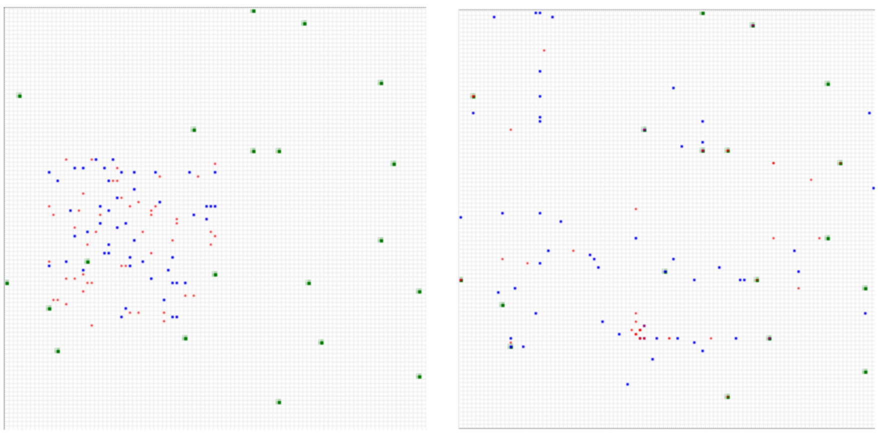
So initially we had to ensure that for the resource-energy condition in our society actually gives a more or less stable world on which investigations when done, and thus we check that the variation of population is stable (even though they may increase/decrease depending on communication level), the stability ratio (total amount of agents currently there / total agents that can be sustained) which are good indicators for the society.



Here we see how there is a stability in the population number as well as in the ratio factors. Among our many results that were produced in the process, we iteratively accepted and developed only those that satisfied these conditions.

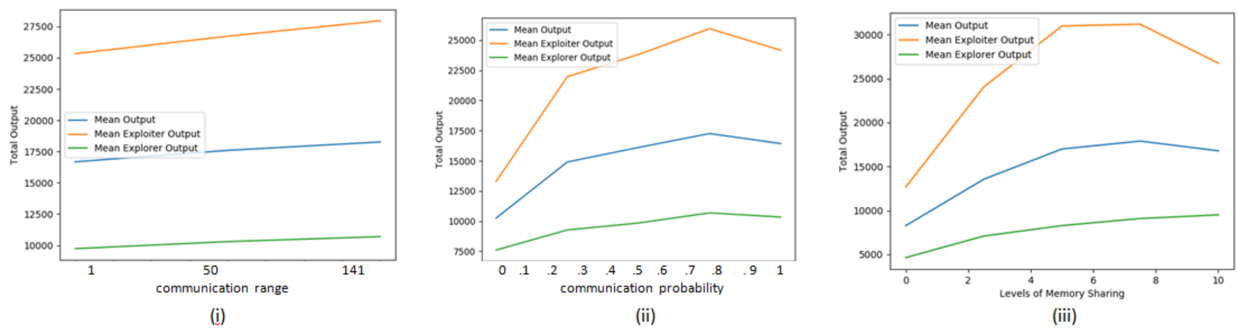
Of the explorer-exploiter ratios tested (0.1, 0.5, 0.9), in this report, cases for only 0.5 ratio is presented

a- the world with competitive societies



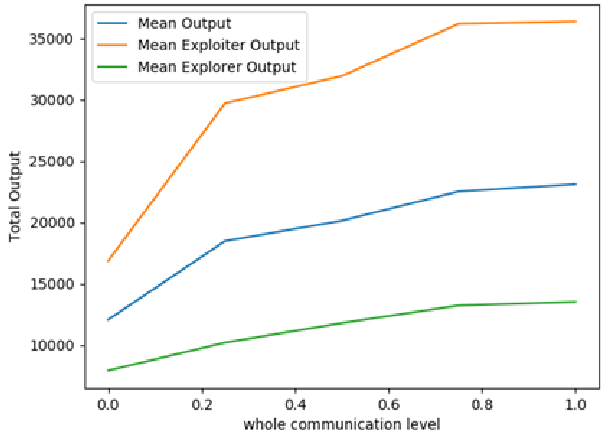
(left) Visualisation of the world while the agents are initialised within their base area. 50 Blue circles are for explorers, 50 red circles for exploiters and green squares for energy-patches.
(right) Visualisation of world after 100 timesteps; agents have drifted across the world finding energy and mining them.

b- effects of communication factors independently on outcome



Variation of total output with varying levels of communication range, communication probability, memory sharing. Output for each level is derived from the multiplicative product of the age and population of the communities for each corresponding level. Separate graphs corresponding to variation of age and population have also been drawn but not represented in this report to keep it specific and pertinent.
(i) as communication range increases from 1 unit to the maximum distance (diagonal), output also increases.
(ii) as communication probability increases (communicate more with agents of similar or different type) output increases.
(iii) the more proportion of information from its memory block that the agent shares, output also increases.

c- communication level as an umbrella factor



This plot reflects how output is affected when all the three parameters of communication range, communication probability and memory sharing are increased in tandem. So for communication level 1, the world runs with all three component parameters are maxed, while with every proportion decrease of communication level, the activity of the components are also by that proportion and at communication level 0, all the component parameters also get valued at 0.
Thus we see that at communication level 0, the output is the least, while it increases sharply with every the first increase communication level and thus activation of the component parameters. Even after that, the output increases, even though it doesn't remain that steep an increase.

Energy sharing as cooperation?

Exploiters can share energy with a probability with the explorers who can borrow when in neighbourhood.
We wanted to check if increase in the levels of energy sharing causes increase in the "output" in the world.
But as per our current investigation, not enough evidences were found for energy sharing affecting output.

3.2 For Competition

We wanted to do a rudimentary test for what would happen if our world consisted of two competing societies.
So we make the world of 3 parts. The right and left consists of space for initial spawning for 2 societies with their depleting energy resources. They are made to mirror each other such that the result is not confounded by uncontrolled factors like the position of spawn of agents or energy resources or the drift of the members in either societies.
The world's middle is a no man's land consisting of a limited number of vertically spawned renewing energy resources.
Our societies compete in the notion of fight for energy resource with the idea that agents from the fitter society should ideally be able to capture more resources when they are made to compete for it.
The no-man's land is inaccessible for the members of either societies forthe first 100 timesteps within which they spread themselves in their own societies consuming their own energy resources, and at 100 timesteps drift with a higher probability drift towards no-man's land as it is opened.
Note: members of one society cannot venture into the area of the other and thus only fight for common resources

Main independent parameters used as competition:

As we have seen, communication level can be taken as a reliable factor for a group's fitness in itself. Our hypothesis for a competition protocol is that the group with higher communication level will be fitter and thus outcompete the other.

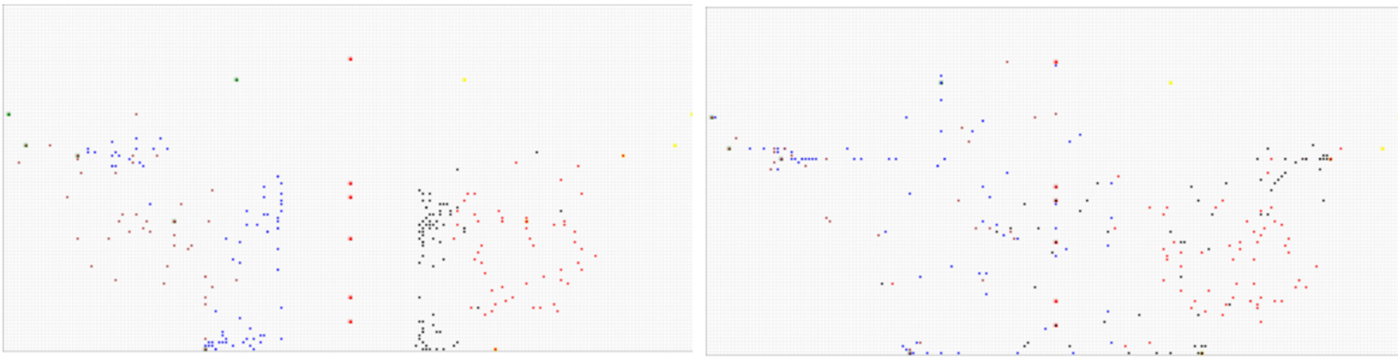
The dependent parameter for competition:

The way one group is supposed to outcompete the other in our protocol is by capturing significantly more number of energy resources in the no-man's land. In ideal capture module, the members of the society whose agents are more in number in that resource will oust members of the society with lower numbers after a particular timestep and for a particular amount of following timesteps, thereby essentially "capturing" or "owning" the resource.

But our ousting module failed due to some development issue and thus we executed a more simpler capture protocol- that where the society whose members are more in one no-man's-land-resource than that of the other society is essentially said to "own" that resource without the need of ousting anyone else. Since superiority of number of agents is also criteria for the ousting module, we decide this to be a fair reduction.

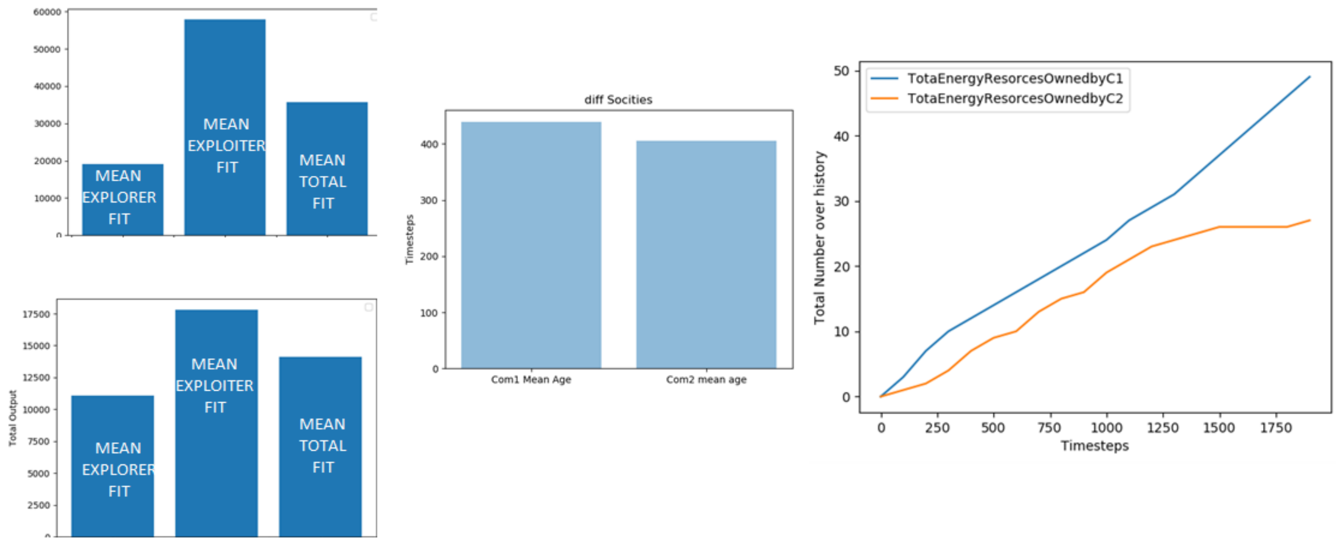
Results

a- the world with competitive societies



(left) Visualisation of the world before 100 timesteps while the agents are restricted within the area of their own societies. In the middle is the no-man's land with its energy resources vertically along the midpoint of the world width, so that they are equidistant from both societies. One may note, that the societies on either side are mirror images of each other. (right) Visualisation of the world after at around timestep=150 where the no-man's land and its renewing energy resources have been opened up for exploration. We can see that some energy resource in both of the societies have got depleted and that sources in no-man's land are gradually being captured by agents.

b- result from competitive societies



Here we see the outcomes from two societies following our competition protocol where communication level for community1 is 0.9 and community2 is 0.3.
-Graphs at the left show how the fitness outcome for the community1 with higher communication level (left-top) is better than the community with lower communication level (left- bottom)
-The middle plot is for population age of Community1 (higher cooperation) and Community2(lower cooperation). It is evident how survival is more
-The plot at the right is the most important for this protocol:It plots how much energy resources of the no-man-land are "owned" by members of that community, added over intervals of 100 timesteps. Observations match our hypothesis in that community with higher level of cooperation will additively have ownership of more no-man-land energy resources.

4 Conclusion

So we systematically formalised the parameters contributing to cooperation in our world, as per the conceptual protocol and also per emperical evidence. We found that all of them have positive relation with changes in outcomes of fitness. We also brought all three under a common umbrella variable 'communication level' changes in which subsequently alters all the component variable values and world outcomes have also been shown to positively vary, corroborating our hypothesis. We also developed a very rudimentary sensed competition module where the community with higher communication level did additively own more among the common energy resources over time.

5 Future Work

from feedback

It was advised that rather than treating and checking for energy resources as an independent factor of cooperation in itself, we can check what would follow if we integrated energy sharing with communication, in the sense that an explorer will share more information with that exploiter who has shared energy with him. We think this suggestion to show significant effect and so i will work and follow up on this.

improvements necessary from my own perspective

We need to make the model way more sophisticated, also in terms of planning and action of the agents in the world.
-Implement a sense of learning, group thinking, protocols for deciding and acting individually and collectively.
-Improve the processing of information as it has little use if it cannot be acted upon in a more sophisticated manner.
-Incorporate the sharing of information with judgement. Receiver puts values to the information based on its content. Thus, for partial information sharing, if someone gives decay rate, time, but not location, then receiver should be able to value that less as the information is useless. We think a Weighted information exchange formula can serve the bill.
-The society should learn to value cooperators over non-cooperators and thus enrich truthfully reciprocating societies.

References

[1] Kopelman Factors influencing cooperation in commons dilemmas: A review of experimental psychological research

[2] Agent based modelling softwares

[3] MESA

Others:

= The Evolution of Cooperation - Robert Axelrod
= The complexity of Cooperation- Agent Based Models of Competition and Collaboration
= Growing Artificial Societies - Joshua M. Epstein