Malini Pathakota
Claudia Chen
Nicole Mehring
Karishma Tangella

Final Write Up

INTRODUCTION

In scientific experiments, it is important that we are able to recreate experiments in order to test the validity of the results (within a certain statistical range). This allows scientists to extend these experiments by adding new features, using different generalizations, etc. There are essentially two kinds of replication, direct (exact) and conceptual replication. Direct replication is trying to replicate the original research as closely as possible, while conceptual replication, assumptions are more flexible. Here, different sample sizes and parameters can be used to study the effects it has on its independent variables.

The same applies for agent-based modeling. We can replicate a code to check the original researcher's assumptions and results. We can then extend this agent based model to test new hypotheses and gather new data and results. This can in turn lead to new insights and open the door for more extensions!

When we do a conceptual replication with agent based modeling, we started by analyzing the base-level assumptions and theories, and build a model without adhering to the exact methods used by the original researcher. Often times, parts of the model can be done differently. We want to see if the results are robust, and if they're not, what are the explanations for the discrepancies. In this project, we do a conceptual replication of Akitipis's cooperation strategy studying agent based model.

Early research suggests cooperation evolved from complex strategies such as tit-for-tat (TFT) and PAVLOV. TFT copies the behavior of its last partner whereas PAVLOV switches its behavior whenever its partner defects (from defection to cooperation and vice versa). There is a mobile and stationary version of both, the difference being that mobile agents move when there is no partner readily accessible. For realistic TFT, agents move and switch their strategy. Walk Away, the strategy devised by Akitipis, is an even simpler strategy than the previous two: it always cooperates/defects and simply moves away from a defecting partner. Other simulations do not truly use space; strategies expand into places where other strategies once were, but individuals never move. There is either space with no movement, and vice versa. Since the study of interaction relies on both movement and space, and ABMs utilize both, alongside the ability to mimic the biological and social world with manipulable parameters, it is appropriate to use an ABM.

In this study, we replicate Aktipis's Prisoner Dilemma ABM, with spatial and mobile aspects, different cooperation strategies (Walk Away, TFT, and PAVLOV, naive), margins of error, energy levels, modified in Lab 3 with REALISTIC_TFT, local reproduction, and agents only spawning in empty locations, and continue to extend it. Those extensions include enforcing maximum capacity without an unrealistic depletion of resources, and a new strategy, which we call RETREAT. Under these conditions, what strategies will be dominant? Why? And how does it relate to the original research?

MODEL DESCRIPTION

In the simulation, each agent has an initial energy level of 10-49, and if it depletes to 0 it dies. This is a modification from Aktipis's original model (her's began from 0-49) as some agents would begin with 0 and die immediately. Agents spawned only in empty locations (another modification from Aktipis's model). The only source of energy aside from its initial source is through interactions with other agents. The user sets the amount of agents for each and any strategy (walk away, naive cooperation/defection, mobile and stationary TFT, and mobile and stationary PAVLOV).

Walk Away, an even simpler strategy than the previous two, always cooperates/defects (depending which Walk Away it is) and simply moves away from a defecting partner. Naive cooperation/defection simply cooperated/defected no matter what. Tit-for-tat (TFT) TFT copies the behavior of its last partner. PAVLOV switches its behavior whenever its partner defects (from defection to cooperation and vice versa). There is a mobile and stationary version of both, the difference is mobile agents move when there is no partner. REALISTIC_TFT, is added. This strategy moves and switches its behavior if the agent employing this strategy is defected against. Our new strategy, RETREAT, cooperates initially, moving at each time step, however, the moment its partner defects, the agent(s) under this strategy only defect onwards, regardless of whatever their partner cooperates/defects. This was influenced from the effects of what happens when someone who was initially cooperative becomes jaded by the world after one betrayal, and thus defects forever. It was also encouraged by people who abandon any kind ideals and roam aimlessly through different environments.

Agents moved randomly and interacted based on their assigned strategy under the circumstances of prisoner's dilemma. They moved or stayed depending on their cooperation strategy. In our simulation, they all move at the first time-step regardless of strategy, then froze/kept moving according to their strategy. If an agent moved to a patch with a pair, it is randomly paired off with one of the two, and can unknowingly break a dyad. There was also a probability for error included, and agents are only inserted at empty locations. Local reproduction, when on, spawns agents near or far from their parents depending on whether or not it is on. A maximum carrying capacity for the simulation is decided at the beginning, and it is enforced by allowing an agent to reproduce when it has the resources, even if carrying capacity is reached. It will then randomly select another agent in the simulation to remove, it could even be the newly spawned offspring. This is similar to how Aktipis enforces carrying capacity, but without randomly eliminating resources from agents.

RESULTS (Text)

Across most parameters (varying amounts of agents with different strategies in different initial conditions and different probability of random movement), the dominant strategy was Walk Away, mobile TFT, REALISTIC_TFT, and mobile PAVLOV, with some representation of defectors and RETREAT. Naive cooperators get quickly taken advantage of and die, while naive defectors exhaust their resources and diminish, but not at the rate of their cooperative

counterparts. Mobile TFT and REALISTIC_TFT as they were not continuously exploited (like naive cooperators) and they copy the strategy that becomes preferred (as the simulation runs, more agents are cooperating since they have the resources to keep living). As there are less defectors, PAVLOV will switch less also. Our strategy performed similarly to naive defection, as after its partner defects, it defects forever. Thus, it exhausts its resources similarly to naive defection, but still has some representation as it can still exploit cooperative agents. Walk Away is the most successful because it can make use of cooperating strategies and denying defecting ones by staying/walking away. It is also successful in high error rates, as it can simply walk away an agent whom they are not benefiting from.

Local reproduction does not affect the ABM prisoner's dilemma model, although it is more realistic spatially. There is little difference because it is not dependent on proximity to the parent, especially with the mobile agents as they will move within the next time step regardless. Agents will be paired off with a random agents of any strategy regardless if they are spawned locally or not. There is, however, more representation for RETREAT as spawning near its parents and its constant movement can cause less opportunity for defection (since first defection causes defecting forever) and more opportunity for exploitation if it does defect.

When we increase the radius of reproduction/play radius, the naive agents surrounded by cooperators before now disappear slightly quicker due to the fact that even if they're surrounded by cooperators, there is more space for defectors to move around, so regardless they will disappear faster. However, this effect is small and not entirely noticeable at first glance.

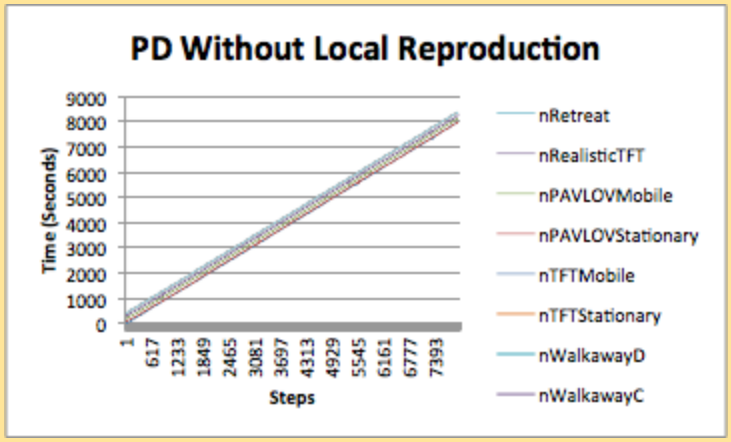
Even when we modified TFT to be more realistic in Lab 3, we did not see any noticeable differences. This may be because, the core of TFT of switching behavior remains the same, thus there is no dramatic variation.

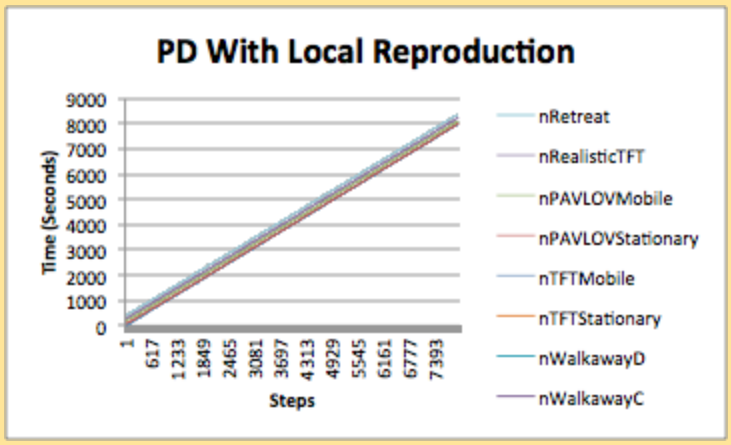
We initially predicted that the new capacity enforcement would not have a significant effect on the results. However, when it was enforced, the results caused stationary TFT, cooperative Walk Away all die out. This is because the without the unrealistic depression of resources allow defectors to reproduce without consequence and allow them to continue to reproduce and overtake. Our strategy also performed well under this condition as it eventually becomes naive defection or it is able to stay around agents who cooperate with it and not defect (it's almost impossible to go through the simulation without encountering one partner who defects).

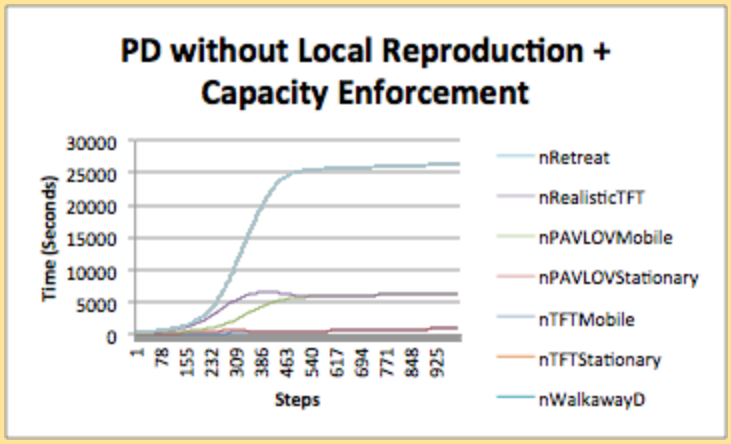
When agents must spawn locally and the alternate carrying capacity method is enforced, agents tend to group up with their corresponding strategy. Because the new enforcement cap allows unlimited reproduction of an agent of its strategy, and to be spawned nearby, they will interact with each other. Without the alternate carrying capacity enforced, the depletion of resources could cause more random agents to die off/be closed to dying, not allowing these alliances to form.

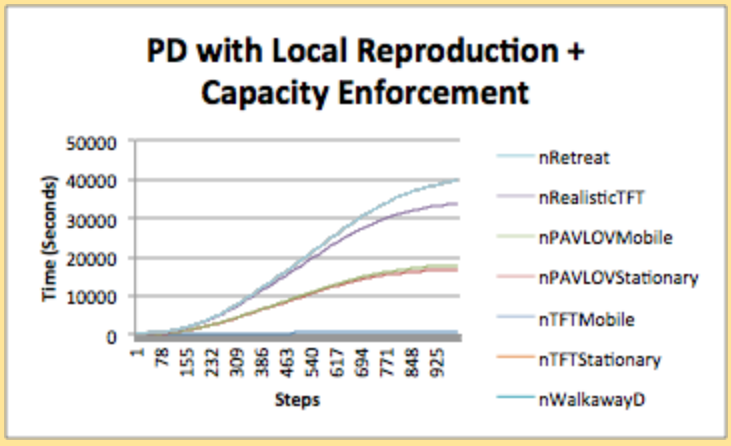
In high error rates, mobile TFT and REALISTIC_TFT is the most successful (since its behavior switches, errors affect it little), while extreme ones prefer naive defection (since it gives a higher rate of exploitation of naive cooperators).

RESULTS (Graphs)









Here, in the first two graphs, we see that local reproduction, enforced or not, has only a minor effect. This is because most agents are mobile, and end up moving away from their parents the time step after their creation. Agents will be paired off randomly no matter what, so there is very little likelihood that they will pair off with their parents, or with someone of their strategy. RETREAT has more representation here because its movement and being near their parents may cause them not to defect, or if they do, they have more chances to take advantage of cooperators.

In the third and fourth graph, we see how there is no longer a linear pattern of agents dying off. RETREAT does well as it can stay around those who cooperate with it and never ends up defecting, or if it does, it can end up in a group where it has the opportunity to exploit cooperators.

However, along with seeing there is not a dramatic effect of local reproduction being on or off, there is an effect when it is on along with capacity enforcement. When capacity enforcement is switched on, regardless of local reproduction being toggled or not, it causes the simulation to take much longer than if it were switched off.

CONCLUSION (Results Discussion)

To answer our original research questions, the strategies that were most dominant, in order, across multiple different initial conditions, were, Walk Away, mobile and REALISTIC TFT, and mobile PAVLOV. RETREAT and naive defection had some representation.

Walk aways is so successful bc it didn't let its users get taken advantage of and had mutual cooperation. Walk away strategy is the most stable as it minimizes benefits to defectors. PAVLOV can imitate this by its switching strategy. Defection causes depletion of energy. Walk away and tft can be similar, but walk away continuously looks for a cooperative partner, while tft just takes whoever's there and keeps interacting with them. Walk away doesn't need memory, which can be important in studying animal behavior.

It did not matter whether agents had to reproduce near or far, because agents would immediately be paired off randomly, and depending on their strategy, could move shortly afterwards. It is very unlikely that, even if they spawn near their parents, they will match with

them. Since offspring can move and reproduce somewhere else, it makes no effect. Increasing the production radius also has no effect as agents will be paired with a random agent regardless.

Increase the radius of reproduction/play radius, it allows naive cooperators die off more quickly because defectors have more opportunity to take advantage of them. This is a very minor effect as naive cooperators die off either way.

We originally thought the new carrying capacity method would not have much of an effect on our ABM, as essentially a random agent is still being killed off to make room for reproduction, thus making it similar to Aktipis's . This actually caused stationary TFT, cooperative Walk Away all die out. This is because without the random deletion of resources, defecting strategy (like ours) have more opportunity to reproduce. When the new carrying capacity is enforced along with agents being forced to spawn near their parents, groups of just one or two strategies form. They are able to aggregate their resources, but the continual reproduction causes more and more agents to die off. As resources become more limited in these pockets, they eventually die off, with cooperative Walk Away able to hold onto its resources the longest as it simply continuously looks for a partner to provide them what they want.

Error rates caused mobile and REALISTIC TFT to thrive, as the errors had little effect on their switching behavior. These errors caused the other strategies to suffer, however, as those strategies are contingent on consistency.

Walk Away's success essentially shows survival and evolution prefers cooperation, as organisms move away from partners and environments that are not fulfilling their needs. Our strategy fails as defection cannot hold onto its resources.

CONCLUSION (Connection to Real World)

We see these results in the real world. Humans walk away all the time in their existing lives. We leave toxic relationships, unappreciative environments, and look for situations we can thrive in, promoting cooperation and contingent movement. We also do tit-for-tat and PAVLOV all the time. We treat others how they treat us, and we may treat others a certain way until someone else shows us differently (we can be distasteful towards others until a kind person opens up our eyes, vice versa). Naively kind people get taken advantage of all the time (we all know someone who gets used), while naively cruel people don't make it very far in everyday life (uncooperative teammates being reported to HR). Our new strategy, RETREAT, initially cooperating and then defecting when defected, is similar to how people become jaded after repeated negative interactions.

Agents only being able to reproduce when they have enough resources is similar to the real world also. Typically, we can only start families when we are ready/have the resources to do so. Those resources include, time, money, and mental maturity. Reproduction is also similar in this sense, as children usually inherit salient characteristics from their parents, and in the simulation offspring take on the strategy of their parents.

The radii (the mobility and spatial elements) of the simulation makes it even more similar to the real world as we as individuals are not confined to only one location. We move through many different settings in our lifetimes, whether they be social, educational, etc.

Error rates mimic some of our social interactions. We may unintentionally hurt the people we love, and treat the people who do not deserve it with kindness.

The addition of local reproduction is important as children in the real world stay near their parents, it's unlike our world in the sense that offspring almost immediately move away from their parents. Without it being on, it could be a metaphor for parents who leave their kids to learn about how to interact with their surroundings on their own.

In terms of carrying capacity, that is unlike the real world in that people do not need to die in order for other people to be born. With our new carrying capacity and offspring being spawned near their parents, it does reflect more on our environment as people typically interact with people who are similar to themselves, referring to the homogenized groups we saw.

Here, we can see the necessity of using an ABM as it is able to mimic mobile and spatial environments and follow agents throughout their lifetimes. It also allows us to see how their individual interactions affect group dynamics. We see discussed above the similarities it has with the real world, but of course have their limitations, discussed below.

CONCLUSION (Future Directions)

All in all, Walk Away is able to model the behavior of extremely simple organisms that are unable to retain memory. Some of the strengths in this simulation were its depletion of energy for defectors, in a way acting as a punishment for them, and its ability to model complex behaviors through simple interactions (defectors taking advantage of cooperators).

Other strengths, as discussed above, include its ability to mimic many different kinds of strategies that we employ in the real world. The ability for agents to only reproduce with enough resources is similar to family structure in the real world. The margin of error reflects how we accidentally mistreat others.

One of the biggest limitations of the model was the agents' inability to have memory, because in the real world we would generally avoid people who have wronged us. Another weakness I saw were that it did not take into consideration other important aspects of a social environment, such as gossip and reputation, as we tell our friends about people who have hurt us or people build reputations as kind or not. One implementation that could improve the ABM would be including a mechanism for reputation and gossip. Agents could have scores associated with their social reputation. The higher the reputation, the higher the probability that they will cooperate.

The time it takes to reproduce offspring, however, is less realistic. Gestation/adoption periods last months in the real world, but reproduction happens instantly here. This can be corrected by making a fixed amount of time steps it takes for agents to reproduce. They could also be moved to an empty location as to imitate an actual child-rearing process.

Another weakness is interactions causing agents to change strategies completely. If the world has been repeatedly cruel / kind to someone in the real world, that would influence how they would treat people later in life. We often switch how we treat people based on how we've been treated in the past. We tried to implement something like this through RETREAT, as bitter encounters could cause people to defect onwards. Algorithms or new booleans and values can make the ABM more correctly mimic the real world.

One way we may test our ABM in the real world through controlled, spatial environments. An experiment replicating Prisoner's Dilemma can be done by having an entire class with varying amount of resources. Some will stay outside the classroom and some will stay

inside. The ones inside are each assigned a strategy. They pair off, and can only stay with their partner at most twice. They initiate their interaction by being back to back, then turning around on the count of three with a thumb-up or thumbs-down. Thumbs-up represents cooperation, and thumbs-down represents defection. Their resources increase/decrease according to what each partner does. Depletion of resources forces people to leave the classroom. When someone has enough resources, someone from outside can come in and take up their strategy. We see here how a real world experiment can get messy really fast, and why an ABM is preferred. This is not a perfect replication, but it can be a way to teach others the effects of cooperation.

Another way is to use interviews with measures on what is cooperation (altruism, helping others) and defection (non-cooperation, being defiant). These interviews can shed light on what makes people feel the best, we can then ask them to name certain situations where they have done TFT, PAVLOV, Walk Away, etc. and rank how each one of them made them feel. These ranks can be used as measures to the success of each strategy.

The study in a way, promotes just walking away from situations that aren't best for one's self. It's more efficient to walk away rather than engage at all with a defector. It also reminds us there are more advantages to be kind and to cooperate, than there is to defect.