# Parochial Altruism in a Robust-First Computational Architecture

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**Abstract**

Computational models of biological evolution have shown that both parochial and altruistic behaviors increase the fitness of the host by working in concert rather than on their own beneficial merits. The benefits of these mutually reinforcing behaviors include better resource management within an in-group propelled by the elimination of out-groups. We present new models that allow for the evolution of parochial altruism in a robust-first architecture that show whether the biological benefits gained from these behaviors can find a correlate effect on fitness in this computational environment. Variations in the willingess of the host to engage in these behaviors as a function of resource supply show a significant shift in benefits for the given behavior. The new models display a dynamic interplay among these evolved behaviors as the populations compete for computational resources.

## Introduction

The paradigm of robust-first computing seeks to promote the robustness of a software program over efficiency or even accuracy. The Moveable Feast Machine (MFM) is a computational architecture based on the robust-first paradigm. The framework consists of element programs which interact with each other in a spatially-distributed and indefinitely scalable environment to create emergent computational behaviors. An introduction to the system can be read in (Ackley 2013) and (Ackley and Cannon 2011). In the MFM, elements must work with finite resources despite an environment of indefinite scalability. Often, each atom of an element (instances of that element program) must interact with each other in order to generate useful computations. Likewiaw, atoms of different elements can work in concert to produce computationaly useful results e.g. Demon Horde Sort.

Other elements can be less cooperative. There are 'forkbomb' elements that are designed to copy themselves without limit until there is no more space to reproduce. While this is the complete opposite end of the spectrum and represents a kind of apocalyptic threat to the system, one can start to appreciate a range of behaviors in between as elemental programs compete for spatial resources in the MFM world. This is reminiscent of biological systems that compete for resources. In evolution, the phenotypical behaviors that arise from the genetic makeup of the population will have a strong influence on the fitness and overall sucess of that population. We seek to analyze some of these behaviors and whether the biological payoff that organisms receive can also be enjoyed by the elemental organisms of the MFM.

Parochial Altruism is one example of an evolved behavior that influences tribal cooperation by helping to maintain a social order, and through cooperation, tribes flourish. Parochial Altruism is expressed in a number of ways such as punishers protecting in-group victims of norm violaters much more than out-group, (Bernhard et al. 2011) in-group contingent Altruism, (Garcia and van den Bergh 2010) and willingness to engage in warfare with out-group members on behalf of an in-group (Choi and Bowles 2007). The tendency to engage in this behavior can be triggered by arbitrary and even trivial group distinctions (Hammond and Axelrod 2006) thus the benefits of parochial altruism extend beyond strictly kin to a much more broad notion of tribe.

This paper will outline research that seeks to explore the evolution of parochial altruism in biological systems by modeling this behavior in a robust-first computational environment. We seek to determine whether the natural evolution of parochial altruism in the biological world, and the increased fitness that it brings, will find a correlate advantage to the elemental programs of robust-first computation, thereby increasing the overall fitness of those programs.

We will create an elemental program that can take on one of four behavior categories: Parochial Altruists, Non-Parochial Altruists, Parochial Non-Altruists, and Non-Parochial Non-Altruists. We will allow these elements to interact with each other, both within an in-group of elements and other out-group elements, in a manner consistent with their behavior, and allow sexual reproduction that produces offspring programs with a genetic mix of the behavior patterns of both parents, subject to mutation, thereby modeling an evolutionary system. By varying the willingess of the agents to engage in their phenotypical behavior as a function of the resources available to the agent, we show a shift in the dominant behavior categories of a given population.

We call this model simulation Paralta, and it is run on the MFM.

## Model Description

The Paralta simulation consists of two elements from the MFM: DREGs and RES, and introduces one new element: Sytizen, which represents a denizen of the simulation world. The DREG parameters are kept primarily the same with the exception of spawning RES with probability 0.02. This allows a sufficient amount of RES to sustain a meaningful population of Sytizens, which use the RES for energy.

Each Sytizen is represented by the following parameters: Team - a three-bit value representing the in-group of the Sytizen.

Energy - a nine-bit value

$$0 <= e <= 511 \tag{1}$$

and initialized to 20. RES grant 10 energy when consumed by the Sytizen.

Genotype - the genetic makeup of the Sytizen that determines its overall behavior in the world. This is represented by two, four-bit values:

Parochialism - a Sytizen with Parochial value

$$0 =< p =< 7 \tag{2}$$

is considered non-parochial, while a value

$$7 > p >= 15 \tag{3}$$

is considered parochial.

Altruism - a Sytizen with Altruism value

$$0 =< a =< 7 \tag{4}$$

is considered non-altruistic, while a value

$$7 > a >= 15 \tag{5}$$

is considered altruistic. The Genotype parameter combinations translate to four discrete phenotype categories:

Parochial Altruist (PA) will take on the genetic behavior of both Parochials and Altruists.

Parochial Non-Altruists (PNA) will take on the genetic behavior of Parochials.

Non-Parochial Altruists (NPA) will take on the genetic behavior of Altruists.

Non-Parochial Non-Altruists (NPNA) exhibit no specialized behavior.

### Genetic Behavior

A Sytizen that falls into the Altruist category will engage in their genetic behavior once per simulation event, if the energy of the Sytizen is greater than the threshold set before the simulation begins. If so, the Sytizen will choose an in-group member at random within two Manhattan distance from herself. If the energy of that member is less than the energy of the active Sytizen (less the threshold amount) then the active Sytizen will share half the difference in the two energy amounts to a maximum of 10 energy. The chosen member gains energy in that amount and the active Sytizen will lose energy in the same amount.

Any Sytizen that is considered Parochial will engage in Parochial behavior once per simulation event, if the energy of the Sytizen is greater than the threshold set before the simulation begins. This behavior will happen in addition to the Altruistic behavior, if the Sytizen is considered to be both. The Sytizen will choose one out-group member within Manhattan distance two uniformly at random. The victim will be ”killed” and removed from the simulation with probability 0.5. If the victim is not killed, the attacker herself has a 0.5 probability of dying in the attempt.

### Simulation Events

At the beginning of an event, a Sytizen will first pay a metabolism cost of 1 energy. If this depletes the energy to 0, the Sytizen is removed and the event ended. The neighborhood of the Sytizen is then scanned, and the location and type of any Element or empty space is recorded within a Manhattan distance of four. The Sytizen will then consume one neighboring RES within two Manhattan distance from them. A consumed RES bestows 10 energy on the Sytizen. Then, any genetic-specific behavior is performed as described above if the Sytizen meets the set threshold for behavior engagement (which we go into detail further on).

If the Sytizen is still alive and their total energy is greater than 30, they will attempt to procreate. Any in-group members within a Manhattan distance of four are sorted by energy. If the highest energy amount is greater than 40 RES, that Sytizen is selected to breed. If an empty location is available, an offspring will appear with a starting energy of 20, and the energy of each parent reduced by 10. The offspring will inherit one of the parent’s Altruism values and Parochial values with 0.5 probability each. Thus, a PA and an NPNA could produce any of the 4 categories of phenotype. Once the genes are established, the parochial and altruism values are each subject to mutation with probability 0.02. If a mutation occurs, the new value is increased or decreased by 1 with 0.5 probability.

Finally, the Sytizen engages in movement. All Sytizens are movement-biased towards any RES visible to them in a given event. The normalized locations of any RES within manhattan distance four are summed, and a vector is determined from the directionality of the sum. The coordinates of the position of the active element is considered (0,0). Surrounding location coordinates are relative to the active element. Thus. a single step west is (-1,0), north is (0,1), east is (1,0) and south is (0,-1). The Sytizen element can only take a single step to one of these adjacent spaces if the space is

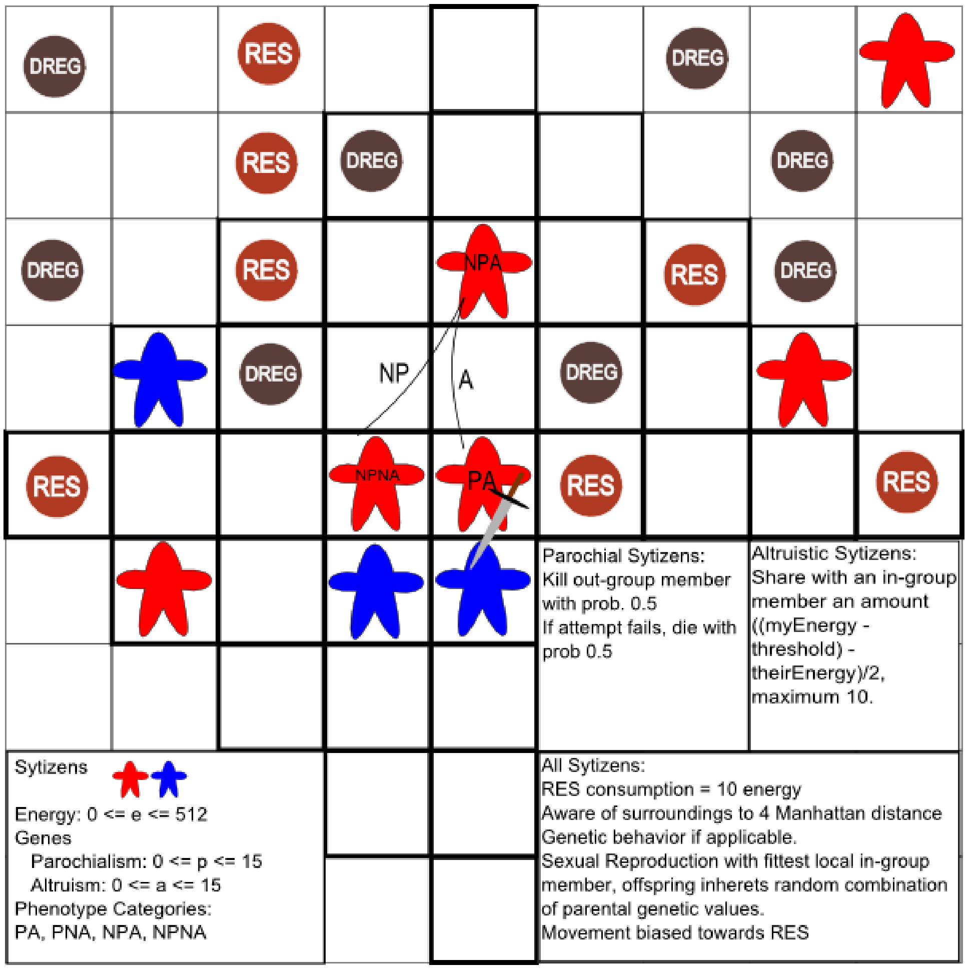


Figure 1: The Paralta Model - A typical step in the simulation. A Parochial Altruist will first consume RES. Then assume an energy above the set threshold, select an out-group member at random, here there are two to choose from, and attempt to attack and remove that Sytizen from the simulation. Then, assuming the criteria is met, will reproduce with another Sytizen, the offspring of which will inheret a combination of the traits of her parents, subject to mutation. Finally, the Sytizen will take a single step in a direction biased towards the RES visible to her.

unoccupied. The sum of the RES locations will inform the Sytizen on which direction to move e.g. a negative x value will bias the Sytizen away from east, a positive y away from north, etc. Of the available adjacent spaces to move, the closest match to our bias is selected. If no RES are present, a random unoccupied adjacent space will be selected. They take a single step, and the event is concluded.

## Methodology

This work is inspired by previous work (Choi and Bowles 2007) which considers the role warfare plays in the evolution of Parochial Altruism. In this model, a tribal in-group can have interactions with outgroups that are both hostile and not, depending on the genetic behavior of the individual, and the posture of the tribe at large. If the tribe engages in warfare, the results of that engagement are applied globally to each tribal population involved, as well as a process of resource sharing among in-group tribal members. While our research is inspired by this work, we not only use a fundamentally different approach, but view the issue through another lense entirely.

In the MFM, there is no concept of a global property as far as the elemental programs running on the architecture. Thus, there is no concept of a tribal decision in Paralta. An individual Sytizen can identify a member of its own in-group (or out-group), and thus can make a distinction as to how to interact with another neighboring Sytizen given a genetic behavior. However, the tribe cannot make group decisions to engage in war with other tribes or share group resources. Thus, we are not considering the evolution of Parochial Altruist from a concept of tribal warfare.

Rather, the interactions among agents are restricted to the individual territory of the agents themselves, reflecting a period before social coagulation took hold with early hominids, roughly 3-5 million years ago. This muddies the waters a little bit on what it exactly means to be an in-group, though (Judge and Langdon 2011) points out that the process of forming groups was gradual and it would be on the order of millions of years before societies were more firmly established. Thus, Parochials are always at war, and will attack other out-group members if able. Likewise, Altruists will share with other in-group members if a need threshold is met, but there is no tribal pool of resources to distribute among all members.

What this paper does not do is seek to explain the emergence of Parochial Altruism in a developmentally significant time period of human history. Instead, we look to analyze the performance of each behavior category in a robust-first environment. As the MFM is a spatially-distributed architecture that provides a limited form of resources both in terms of space and memory to each elemental program running in it, we seek to determine whether biological traits that evolved naturally in the environment will find analgous benefit to the competitive environment of the MFM. If programs (and potentially rogue programs) find themselves in a space to compete for resources, is there a behavior these computational organisms can exhibit to maximize their chance at survival given limited resources? Furthermore, is there a gradient in which an optimal amount of that behavior is more beneficial than another? Is a Parochial program better off being parochial all the time? Would a program that shares its resources with other elemental programs of the same in-group be better of by limiting the amount of resources it does share and if so, how much? These are the kinds of questions we wish to explore with Peralta.

To address these questions, the energy threshold by which a Sytizen will engage in genetic behavior was adjusted over several runs. Initially, this threshold is set to 0, and genetic behavior will be engaged in every turn, if all other conditions are met. Then, we conduct runs at thresholds of 100, 250, 400, and 512 (effectively turning off the genetic behavior). We make 10 simulation runs per threshold.

There are a great many pitfalls in the design of a model wherein a representation is made of a phenotypical behavior that arises from biological evolutionary processes. Such representations are arguably subjective to a degree. It is worth then, at this point, to discuss some of the design elements in the Peralta model. A great deal of care has gone into simplifying the model as much as possible. One of the first challenges was to address a way in which a genetic behavior might express itself from a phenotypical standpoint. What behavior represents a parochial altruist vs. a parochial non-altruist? Initial models specified a unique behavior that a Sytizen would engage in to represent each phenotype category. These representative behaviors all had the common issue of being both assymetrical and somewhat arbitrary in their design. In the end, it was decided that a better approach would be to model a single behavior for altruism, resource sharing with in-groups, and a single behavior for parochialism, aggressive action towards out-groups, and have a Sytizen engage in one or both as their genetic makeup dictates. This allows a binary behavior pattern to eliminate as much noise as possible from the simulations.

Sexual reproduction was chosen to allow for recombinations of genetic behavior as naturally as possible. Because of the spatial constraints of the MFM, this posed quite a challenge in achieving a rate of reproduction that made a population viable. Thus, the range threshold by which a Sytizen can select a partner was relaxed to the full event window range of the MFM, a Manhattan distance of four, to allow procreation beyond the range of movement. While in an abstract sense, this does not represent reality in biological systems in terms of spatial effect, we feel it minimally, or at least uniformly impacts the effectivity of all behavior categories being studied. It likewise maximizes the chance of recombination, by minimizing the noise from genetically identical Sytizens that happen to be clustered near each other only reproducing with themselves. In addition to these steps, we've also introduced mutation into the model to a high degree to offset this notion of a reproductive spiral of genetically-similar agents only reproducing with each other due to being clustered spatially. The mutation system itself introduces another kind of noise into the system by trending the genetic values toward one end or another, a kind of gravity effect, so that we see one or two behavior categories dominating a particular control simulation run. To help offset this, we make numerous simulation runs at each behavior threshold to dilute any potential effects.

The other interaction ranges were likewise relaxed; the range at which a Sytizen can share with or attempt to kill another Sytizen is Manhattan distance two. Likewise, the distance at which a Sytizen can consume RES is also two. We recognize a tension between the concept of affecting the surrounding world at a range that is greater than that which you can physically move, and the architectural properties of the MFM, whereby a program can read or write to the entire neighborhood of four spaces away from it. Setting the effective distance to two represented a compromise between these opposing considerations, and indeed a series of variant runs in which the distance of effect was varried indicated no significant difference between results.

The simulation world of the MFM map used is a grid of 5 x 3 tiles, each of which contains 32 x 32 cells each of which is considered a single space in the MFM world. Only one element may occupy a space at a time. The initial configuration of the Paralta simulation is identical for every simulation run with the sole exception of the varying behavior threshold. Arrangement of each tribe is symmetrical on the map, with tribe one staged on tile (2,2) and tribe two stage on

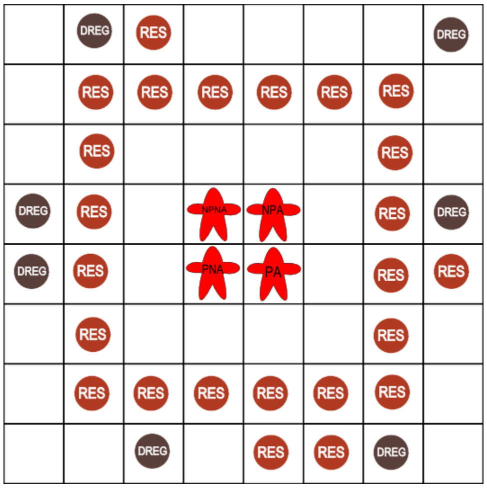


Figure 2: Initial configuration of the Paralta simulation. Sytizens are surrounded with a single layer of RES at a distance of 1 to help ensure an increase in energy amount enough to engage in initial reproduction.

tile (4,2). The 'egg' of each tribe is placed centrally within the tile and consists of one member of each behavior category surrounded completely with RES elements to minimize the chance of 'false starts' with tribes failing to spark an inital round of reproduction by moving away from each other before obtaining an amount of energy required to reproduce. (See figure 2).

Before the Sytizens are placed in their starting configurations, the simulation is run for a period of time such that DREG and RES elements achieve a stabilization throughout the map. This creates an environment where the DREG population will already be what it will remain as (on average) throughout the run of the simulation. RES, on the other hand, will be in significant surplus at the start of the simulation, which we discuss below.

This initial configuration has two side effects worth noting. First, the initial population will be significantly influenced by whichever two Sytizens happen to reproduce first. By extension, we recognize that this can have a lasting effect over the life of a given simulation, the effects of which we mitigate by conducting a series of runs to weed out statistical anomalies. Secondly, the initial surplus of RES will cause a population explosion at the beginning of the simulation run, once the initial tribal 'eggs' have been arranged. This population boom is immediately followed by a drop as the surplus tribal populations die out without enough RES to sustain them. Very rapidly, the population stabilizes at a range of 200 to 300 Sytizens globally, and maintains that level for the duration of the simulation. This entire process, from boom to stabilization takes approximately 120 AEPS, out of a total simulation time of 20,000-100,000 AEPS. Thus, for ease of visualizations of the data, we truncate the initial population boom and only consider the data after the population stabilizes.

## Results

We let each simulation run until one tribe falls to a single member remaining. As repopulation is impossible at this point, we declare the other tribe to be the dominant population and consider the simulation run concluded. Of the behavior categories present in the surviving tribe, we note which category comprises the largest share of the population, and consider that behavior the dominant or winning behavior for that run.

50 simulation runs were conducted accross 5 behavior threshold categories. What we typically see is the emergence of one to two behavior categories in each tribe that stay fairly dominant throught the run. This is particularly the case in the lower behavior thresholds. When the threshold is set to 512, greater than the maximum energy that can be held by any Sytizen, the genetic behavior is effectively 'turned off' and all Sytizens exhibit the identical behavior. That is, they will diffuse around the map, biased towards RES, collect any RES encountered, reproduce with their in-group, but otherwise have no interactions with either in-groups or out-groups. This creates a natural control group by which we expect to see a normal distribution of successful behavior categories throught the series of simulations at this level. This is effectively what we see. What we still do not see is an increase in competition among the behavior categories themselves, again due to the 'gravitational' effects of the mutation system. This behavior threshold is one of the few times we see NPNAs as the dominant behavior of a winning tribe, and we see it twice out of 10 runs. They fare only slightly better than NPAs with only 1 win in this category. PAs follow with 3 wins, and NPAs were the dominant trait of the remaining 4 runs. Though staggered, these results still fall within a normal distribution of wins, again as we expect.

At a behavior threshold of 400 we begin to notice some very slight skewing in wins. NPNAs no longer appear on the board, and the 10 wins are shared evenly accross the other three behaviors, with PAs eeking out a lead with 4 vs. 3 for the other two. Interestingly, the NPNAs do not even appear as a dominant strategy even among the losing team, with the exception of a single run that ended with them in control at a fairly early 20 kAEPS. In a conservative environment, it seems better to at least interact a little with others rather than not at all.

An energy threshold of 250 represents half the maximum possible energy obtainable by a Sytizen. At this threshold we get dramatically different results. Parochial Altruists win an overwhelming seven out of ten runs as the dominant strategy, with each of the other strategies winning one run each. Furthermore, in all three cases when PAs did not win outright, the behavior category that did win had a significant population of PAs present suggesting a strong correlation in

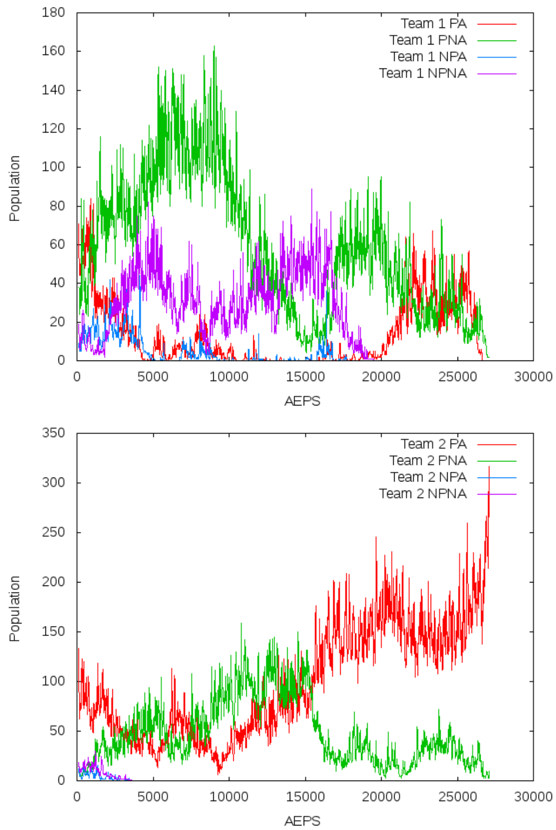


Figure 3: A typical simulation result with energy threshold set to 250. Team One (above) had a significant population of all categories initially, but very quickly became dominated by PNAs and NPNAs. At approximately 20 kAEPS we can see a population of PAs emerging, taking over the spot held by the NPNAs, however it seems the emergence was not enough against an overwhelming out-group of PAs. Team Two (below) was very quickly controlled by PAs and PNAs. As early as 15 kAEPS the PAs begin to overtake the tribe and ultimately overwhelm Team One.

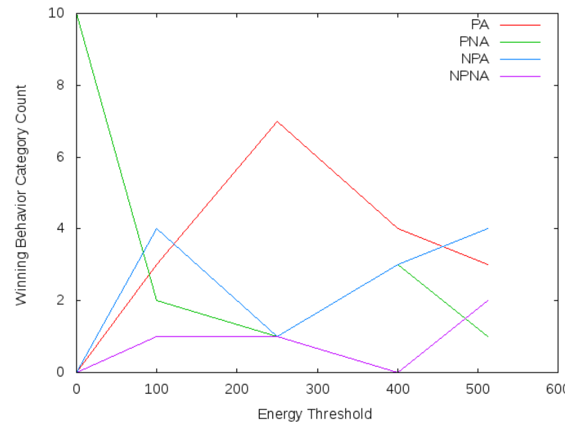


Figure 4: Overall Paralta results.

winning strategy with the PA behavior. Conversely, many of the outright PA victories occurred with populations that consisted solely of PAs with not a single other non-PA present in the tribe. Likewise, PAs manage to win out over tribal populations that exhibit every other kind of behavior category either as the sole dominant behavior of that tribe or in combination with one to two others. Not all possible combinations of these were encountered, and it would be interesting to further study whether certain combinations would hold up better. Of course a population consisting of an even mix of NPAs and PNAs would be a rough equivalent to a population of PAs, and might be merely a numbers game at that point. Indeed, there is at least one simulation where both tribes were dominated by PAs alone and one tribe wins out seemingly due to higher overall numbers throughout the simulation, though this number discrepency is not a factor in other PA victories.

At a threshold of 100 energy, the dominant behavior strategy skews back towards a more evenly distributed set of categories. Though parochialism seems to take a definitive backseat to altruism, and nearly all the wins go to altruistic Sytizens, parochial or not. There were some interesting cases in this category. Among all other simulation runs at higher thresholds, an energy level of 100 was assumed to result in shorter simulation times as the population had a collectively 'itchier trigger finger'. With more propensity to attack other out-group members, the simulation runs should go faster, but indeed this category sees some of the longest runs by far. The longest, at 120 kAEPS had to be stopped before a tribe was eliminated due to the hard drive filling up with simulation data. That said, a quick analysis of this run shows both populations very early dominated by the PA strategy with absolutely no variation and no indication that either side was going to fold any time soon. Thus, the point was comfortably given to PAs for that run.

A zero threshold is the wild west of Paralta. Sytizens at this threshold will share resources or attempt to attack out-group members with no regard whatsoever to their own energy resource levels. Inherent genetic behavior requirements still apply, such as an in-group member must be at a lower energy than the active Sytizen in order for that Sytizen to share with them, and the energy shared is still capped at 10 energy. In such a compulsive environment, Parochial Non-Altruism is the undisputed strategy. This behavior dominated every single run at this threshold. If we are making comparisons to the wild west, this strategy makes intuitive sense. Hold on to what you have, and kill anyone you don't trust. As the global population begins to take their own personal energy into consideration, however, this strategy rapidly declines in effectiveness.

The final picture from all simulation runs shows a few curious trends. Viewing each behavior on its own merits, we see that Parochialism is a viable strategy particularly in environments where there is little or no restriction on behavior. As the Sytizens take their own energy into account more and more, and a more conservative threshold is set on engagement, Altruism begins to emerge as the dominant strategy. In the middle of this range, a mixture of both is the clear winner, as parochial altruism as a strategy wins the majority of the time. It is interesting to note that in addition to a fully conservative environment in which no genetic behaviors are exhibited and we see a normal distribution of wins across all behaviors, there is a similar pattern that emerges at a threshold of 100 energy, or roughly 20

One of the most surprising results is the total domination of PNAs at a threshold of 0. In this enviornment, it is clear that sharing or inaction is out, though the effectiveness drops sharply as the popualtion becomes more conservative. Altruism in general seemed to do surprisingly well, considering that the simulation made altruism a difficult bargain, as Sytizens would give up energy to share with the tribe at a cost to the offspring they could produce in the world. We did consider a world in which altruists would only share with other altruists as a way of offsetting the gain received by non-altruists at no cost to themselves. However a few variant runs showed that the results stayed largely the same.

## Discussion

It's difficult to think of a program as being altruistic, though the idea of a parochialistic program is somewhat more commonplace. Computer viruses and malware spread infectiously from node to node, taking care to not disturb any copies of itself (in-group) if present in an infected computer, and moving on to others. Otherwise, the virus will often hook into existing processes in the computer (out-group), sometimes subverting them, sometimes replacing them. Some even have malicious intent, with the goal of destroying data. So what does it mean to be an altruistic program? Furthermore, a program that is a parochial altruist? To answer that question, let's first consider the enviornment of the program.

The Moveable Feast Machine, and the robust-first paradigm at large, are concepts that are radically different than the computational processes that we're used to. Programs have traditionally had 'full access' to memory in principal. They interact freely with each other, and all can share in some global state that even other programs can be made aware of at any time. It is a full-access pass. This has given rise to a vast array of security issues that have become accepted risks, whether or not they should be acceptable. MFM eschews the traditional approach for one that restricts a program to operating in a limited physical space. An element may have full control over that space, but the damage that can be done is limited. The world becomes smaller for these creatures. This creates a demand for spatial resources, and the programs must compete for that space. Is it enough to rely on the notion that all other programs will 'play nice'? To ensure the robustness of your program, that assumption will not do. So the question becomes how well do you trust your environment?

As we see from our results, if the environment is the wild west, then every program for itself is the likely rule of the day. May the best fork-bomb win. We don't, thankfully, find ourselves in the wild west very often. The winning strategy then it seems is a combination of both parochial and altruistic behavior. So we'll consider possible behaviors of each within the MFM.

Parochialism for an element can mean a number of different approaches in dealing with other elemental programs. In Paralta we modeled a probability of success in such a case, wheras in the reality of the MFM, the element can write directly over that element and the victim has no recourse in this case. If an element finds itself in a limited resource scenario, the first task if deciding to engage in this tactic would be to ascertain what is considered an in-group; e.g. what fellow programs within the event window are necessary to our continued success? It would be unwise to eliminate a program necessary for any computation we need to undetake.

An element can simultaneously engage in a form of Altruism as well. We have already discusses spatial competition, and certainly an element can elect to overwrite itself in the interest of allowing other atoms of its element or even other elements a better chance of doing their work in the process. However, there is also an issue of processing time. Events fire off in the MFM asynchronously. Thus, at any given moment, there are numerous elements running their behaviors and making changes to the world as long as those changes do not interfere with each other. Processor time is this limited, and randomly distributed. So it might be the case that an atom has been given several actions before a neighboring atom has been given a single one. This can be particularly problematic when you have a cluster of common atoms trying to act in concert, saying moving as a single unit, but there is no guarantee as to the order their actions will come. Thus, an element can yield its time in the processor until such time that its neighboring atoms have had a chance to go.

Such behavior options can of course be dialed up and down as the environment around the element changes. If a rogue element is introduced in the system, say a fork-bomb, then the behavior of the indigionous elements can adjust to the same extreme, say an anti-fork-bomb. In fact, such an element already exists in the MFM, with the behavior of diffusing around, careful not to disturb the other elements from their business. Until, that is, a fork-bomb is detected, or other similar program of malicious intent, at which case it converts immediately to a secondary state of erasing every atom of the offending element that it can find. Such tactics help ensure the robustnes of the system as a whole.

## Future Work

This is an extremely young area of research and the field is replete with issues to tackle. The MFM itself is still undergoing continued development and there are a number of interesting engineering issues to tackle. As the focus shifts to robustness, the traditional reliance on accuracy will be at stake. As we must still demand accuracy from our software, new methods must be found to help bolster the performance of this software. Thus software performance itself must needs be improved. This is where software behavior becomes key.

Parochial Altruism may be effective in achieving an increase in reliability and accuracy, but more work must be done. Paralta analyzed a world in which all denizens were on the same conservative page. This will of course not necessarily be the case in the real MFM world. Likewise, Paralta was analyzed using only two tribes, whereas there can be dozens of Element programs operating in the MFM at once. Analysis with more tribes would be useful. Finally, what other behaviors can an element engage in that will enhance accuracy or efficiency? There are likely a wide variety of strategies that can be employed by programs in the kind of ecosystem present in the Movable Feast Machine.

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