NDnano
Center for Nano Science and Technology

NDnano Summer Undergraduate Research
2019 Project Summary

Student name & home university:
Kiran Jain (Indian Institute of Technology, Delhi)

ND faculty name & department:
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Summer Project Title:
Computational Modelling of co-evolutionary genetics in ecosystems

New skills acquired during the summer research:
Through this project, I gained skills on creating algorithms in MATLAB, a computer programming language and learnt using the various tools MATLAB offered. I improved in my knowledge of probability and linear algebra, since their concepts were integral to understanding the theory behind the project I was working on as well as in the creation of programs. I gained knowledge in biophysics, mainly on the mathematics happening behind evolution and genetics when one more one than one species are present in an environment and are interacting with one another.

Practical application/end use of the summer research:
This research aims at finding answers to the evolution of beetles and mites in an ecosystem, helping us understand how the populations of beetles evolve and what are the different parameters and conditions that influence this evolution.

Project abstract:
Beetles are present in a habitat. Each beetle competes with the other members of the beetle species for resources available in the habitat (like food) to survive and produce offspring. However, not all beetles are the same and some are more “fitter” than others, implying that they are more likely to defeat other beetles in a competition for a resource.
Our research has aimed at creating a virtual ecosystem which mimics these real-world interactions amongst the species members to help us find answers to the evolutionary questions like - How does the average beetle size change over time? Who eventually wins this race of evolution? What happens when mites come into picture and interact with the beetles in the ecosystem?
Inclusion of mites into the system makes it even more interesting, since the interactions between the different species varies for every individual. Hence, while there might be positive mutualistic relationships between beetles of some size and mites, there might be parasitic relationship between mites and beetles of another size. This research is hence, also interested in knowing the relationship between size and the mutual interactions between the 2 species.

One-page project summary that describes problem, project goal and activities / results:

In the real world, beetles are found living in a natural habitat. Just like any other species in nature, each beetle competes with the other members of the beetle species for resources available in the habitat (like food) to survive as well as produce offspring to carry on their genes and traits. However, similar to any other species, not all beetles are the same and some are more "fitter" than others, implying that they are more likely to defeat other beetles in a competition for a resource, and hence survive and produce more of themselves. In beetle population specifically, mass is a trait which proves detrimental in deciding which beetle wins in a competition. Further, it has been observed naturally that beetles tend to be accompanied with mites in natural habitats. Experimentally it has been concluded that mites increase the temperature of beetles and statistically the beetles with more number of mites (and hence increased body temperature) tended to win. Hence, body temperature is another parameter which comes into consideration which becomes slightly contributing (yet important) parameter in deciding a competition winner.

In such a complex ecosystem, it is often interesting to ask questions on evolution. How does the population of beetles evolve as time passes? Does the average size of beetles increases due to size offering such a big competitive advantage, or does it decrease simply because the smaller beetles are able to produce more number of children as compared to the larger beetles with the same resource? Does mutation affect the distribution of size? And what happens when the mites come into the system? Do they benefit or compete for the same resources, or both? Are these interactions mutualistic or parasitic?

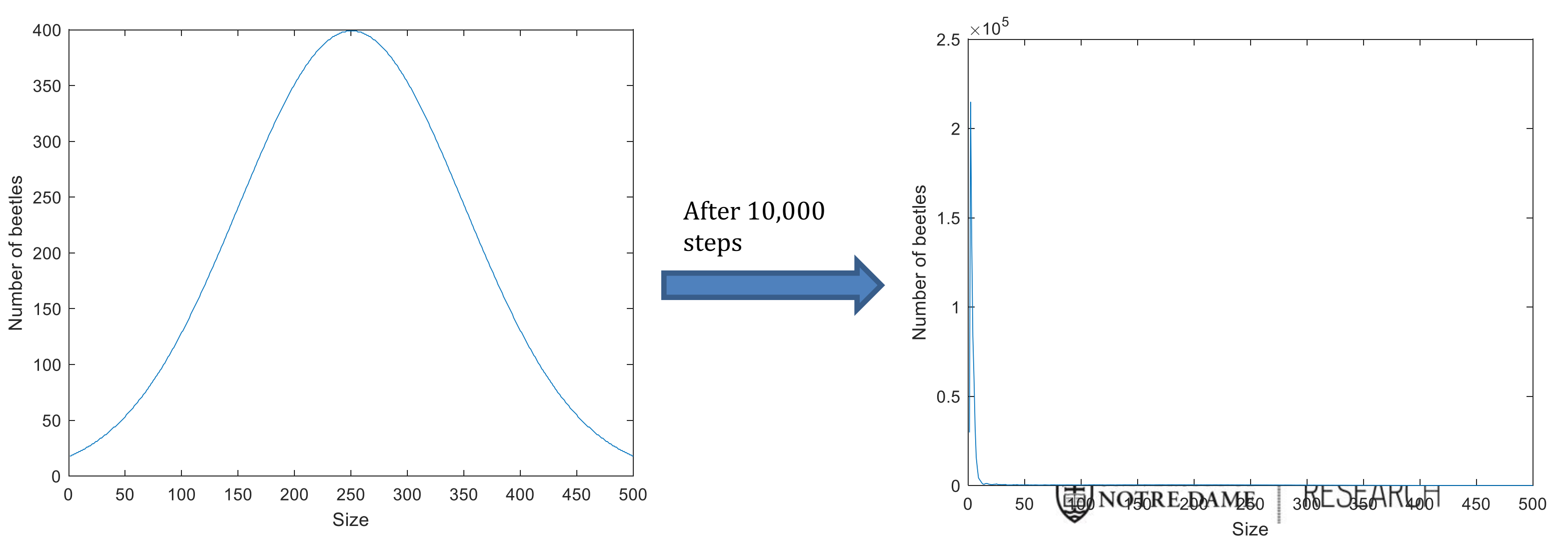
For our research, we created virtual environments using MATLAB to simulate the population of beetles and mites and tried to mimic the natural interactions as much as possible to predict accurate results.

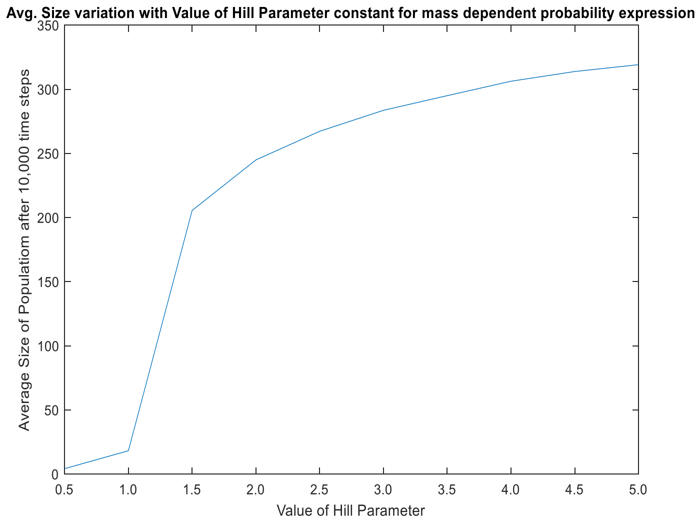
We analyzed that the probability function to decide the winner of a competition between 2 beetles must successfully follow the following 3 criterion –

1. It should be symmetric for the 2 masses involved. If we reversed the masses, the probability function should symmetrically show the complementary value
2. The function should be less than one
3. The sum of P(winning) and P(losing) should be equal to 1

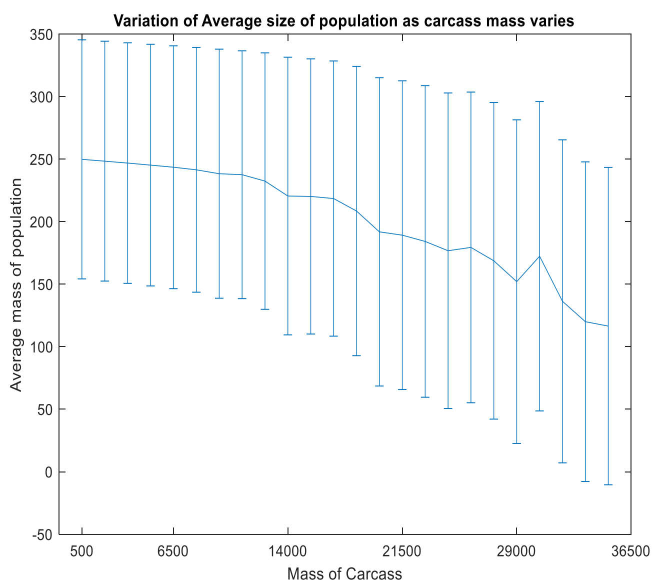
All the 3 conditions seemed to be satisfied by the Hill function which we eventually use for our virtual environment as the probability function to decide the winners of the competition.

The initial population was taken to be a Normal distribution and the population after 10,000 steps was found to be -

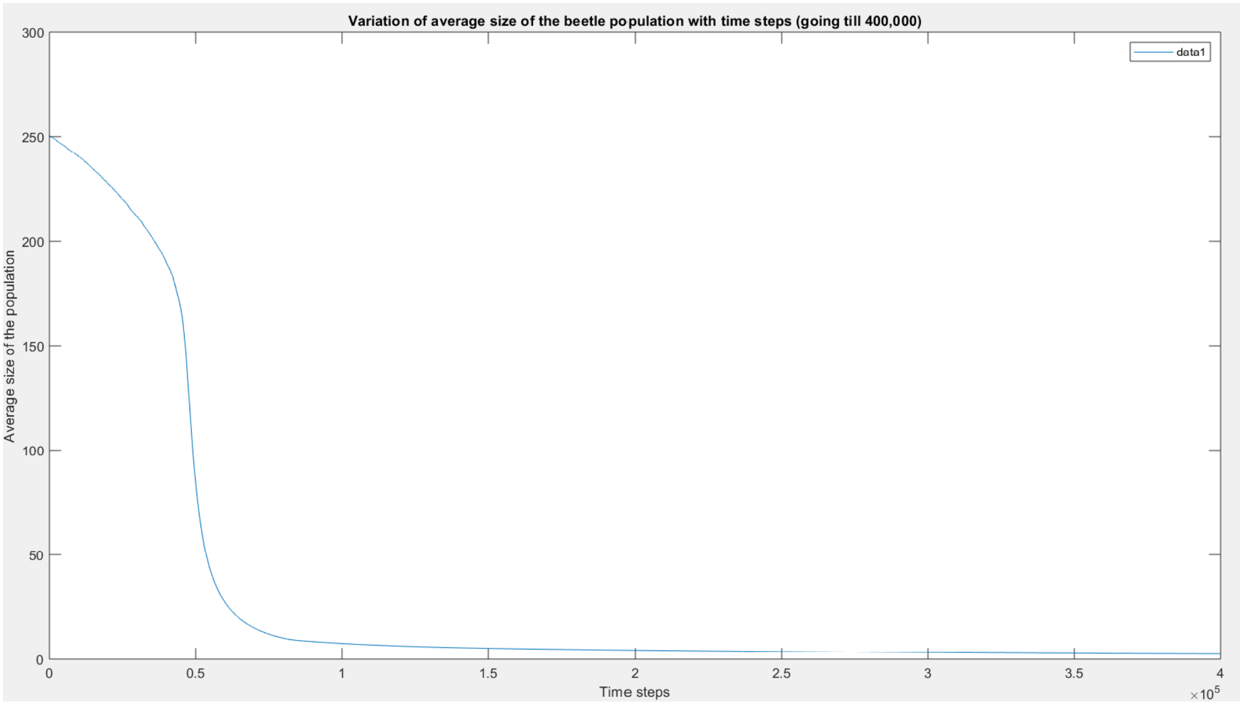




The variation of the average size of the final population with the value of the Hill Parameter. Note that the average size increases as the Hill Parameter increases, simply because increase in the Hill Parameter increases the possibility of larger beetles winning the contest.



As the carcass size increases, the change in the population distribution per iteration increases, leading to achievement of smaller final average sizes in the same time frame.


Variation of average size of the beetle population with time steps (going till 400,000)
data1
Average size of the population
Time steps
0
50
100
150
200
250
300
0.5
1
1.5
2
2.5
3
3.5
4
×10^5