Aditya Madhan

Computer Science

03 January 2023

Simulating Natural Selection

Natural selection is regarded as a universally true phenomenon in modern society. It isn't questioned not only because it is taught in schools around the world, but also that its principal tenets are reasonable. "Organisms with traits that allow them to survive longer than others will pass down those traits to the next generation" is seemingly the key idea of natural selection. While I agreed with it for the most part, there was still one childish question I never truly got answered until recently: why didn't humans (or any animal for that matter) evolve to get super-sight? Surely, an organism that can see for long distances would be much more fit than an organism that isn't able to see as far. By creating a simulator for natural selection, I hoped to answer this simple question.

Outline of the Simulator

The simulator creates a very basic, oversimplified environment for the organisms, or entities as known in the program. There are three different types of entities: carrots, rabbits, and foxes. As might be obvious, the rabbits eat the carrots, and the foxes eat the rabbits. Each cycle, rabbits, foxes, and carrots are randomly placed on the map and set loose. The cycle ends when all entities have perished; in that case, the genes, or attributes of the member of the species who survived the longest will be passed down to the next generation of that species. However, before it is passed down, each attribute will mutate slightly for each entity.

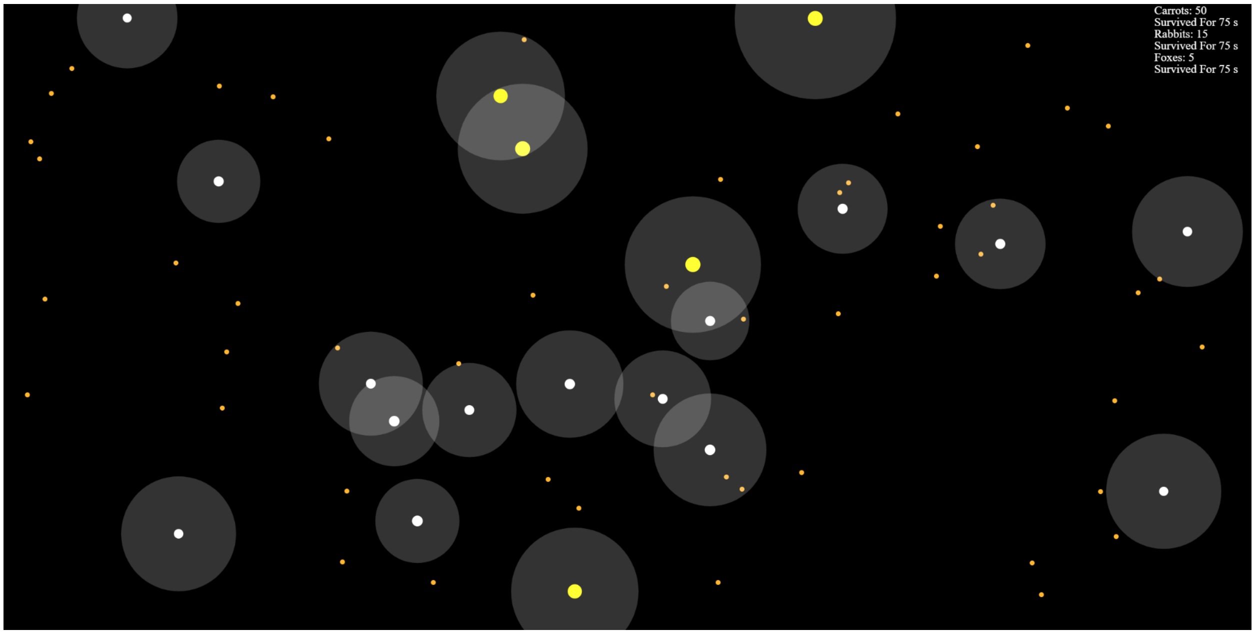

Figure 1: Example of the simulator when it first starts

Each entity has a certain amount of potential energy, measured in joules. This starting amount of energy is determined by the mass of an entity, which will be explained later. Every simulated second (which is equivalent to one frame), entities will attempt to move around, and their total energy is depleted by an amount roughly similar to the amount of kinetic energy expended ($E_K = 0.5mv^2$), When an entity's total energy is completely depleted, they will "die", turning red and becoming immobile. While an entity is alive, it can gain energy by consuming other entities (by being close enough to a prey). When an entity has been consumed, it will become "consumed", turning gray and rendered immobile.

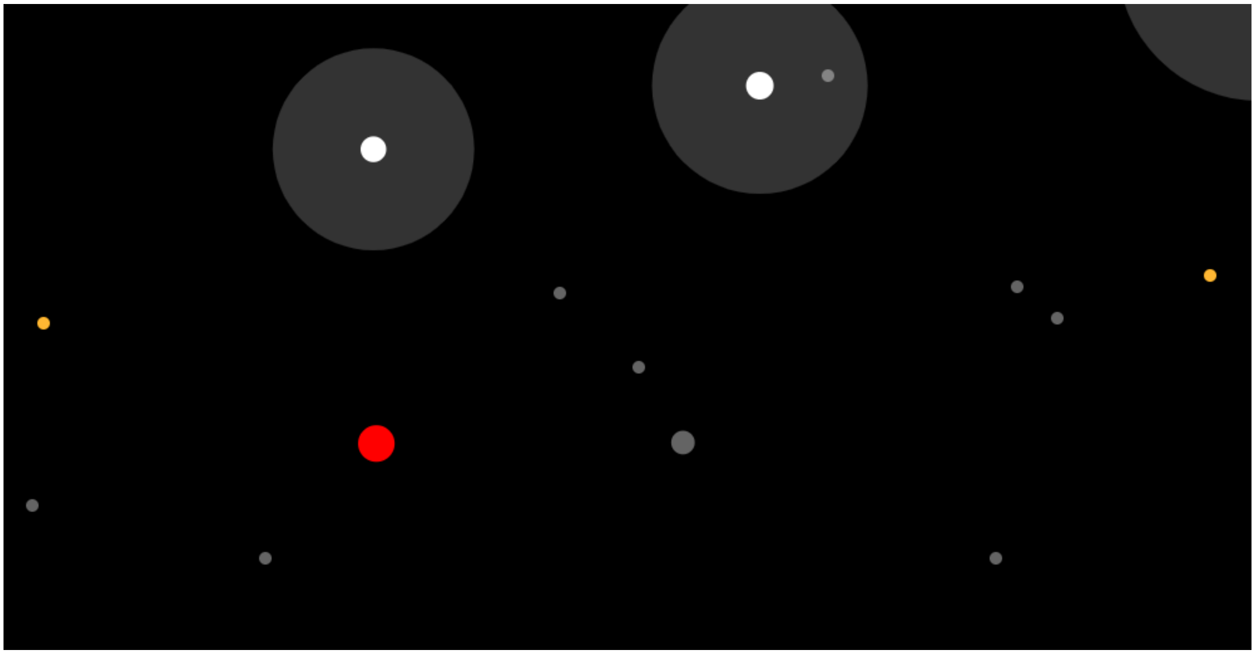

Figure 2: Example of entities that are alive, dead, or consumed.

Traits. Entities have 5 different mutable traits: SPEED, BURST TIME, REDUCED SPEED TIME, MASS, and VISION. Each affects how an entity interacts with its environment.

(1) SPEED is the magnitude of an entity's velocity vector; in other words, the distance traversed per animation frame.

(2) BURST TIME is the amount of time, in animation frames, an entity can maintain a "burst" speed, where the speed increases by 50%.

- Burst is activated when either an entity senses moving prey, or an entity senses a predator.
- Once the burst time limit expires, an entity cannot activate it again until the time limit for reduced speed cools.

(3) REDUCED SPEED TIME is the amount of time, in animation frames, an entity must maintain a "reduced" speed, where the speed decreases by 40%.

- Reduced speed is only activated upon the end of a burst.

(4) MASS is the weight, in kilograms, of an entity. It determines both the initial amount of energy of an entity and the rate at which energy reduces.

- The total energy of an entity, in joules, is its MASS times a base energy amount for all entities.
- The rate at which energy reduces per animation frame is half of the mass times the quantity (v+3) squared, where v is the current speed.
- Mass is visually shown as the size of the entity on the screen.

(5) VISION is the distance for which an entity can see its surroundings. It will act depending on what is within its vision radius

- If there is prey within its radius, the entity will move towards it. It will also burst if the prey is moving
- If there is a predator within its radius, the entity will move away from the predator
    - The entity will burst away from the predator
    - The entity will prioritize running away from the predator rather than going to food, unless its current energy is at 10% or less of its initial energy.
- Vision radius is shown visually by the transparent gray circle surrounding an entity

Most of the traits have both an advantage and a cost to increasing them. Increased speed allows an entity to move faster and therefore increase the likelihood of finding food, but also increases energy loss per second. Increasing burst time allows for an entity to escape predators but increases energy loss dramatically. Decreased “reduced speed time” allows an entity to return to its normal speed faster after a burst, but runs the risk of running out of energy before finding food. Increased mass increases the initial amount of potential energy but also increases the rate of energy loss per second. Vision, however, is a unique trait due to the fact that it does not have any built in demerits.

Predictions and Emergent Behaviors

After I had finished building the model and had started testing it, I expected a few behaviors to emerge. I was very certain that in each run of the model, both the rabbits and the foxes would continue to evolve until they reached a Nash equilibrium: that is, neither species would vary in their attributes much since it would only reduce their survival time. I predicted that they would reach the same equilibrium every single run of the simulator, even if some runs took longer to reach that point than others. I also believed that the vision trait for both foxes and rabbits would continue to increase in size until they encompassed the entire screen (at which point, an increase in vision radius would not impact survivability).

The results, however, told a different story. While I was correct in the fact that both the rabbits and the foxes would reach a Nash equilibrium every time, what I was very wrong about was what the equilibrium was. I had never considered the possibility that there could be multiple equilibriums possible, achieved in different simulations. In one simulation, I viewed the rabbits and foxes moving at incredible speeds, chasing after each other nonstop until both species died out quickly from exhaustion of energy. However, during other simulations, I saw foxes moving at a turtle's pace, simply scavenging for "dead" rabbits and conserving as much energy as possible.

However, the most astonishing result of the simulation was how the vision trait did not expand continuously as I had expected. After a certain point, vision stopped evolving for the rabbits, and after several more cycles, so did the foxes. I was initially confused since I had never programmed in any kind of disadvantage to having a larger vision radius. However, I came to realize that the disadvantage was hidden in the ruleset I had created for the vision trait itself. The reason rabbits weren't able to expand their vision radius was because they experienced an information overload: they were able to see foxes from too far away. Since rabbits prioritized running away from foxes over finding food, they would burst away from foxes even when they would be able to safely get away even without bursting. This burst would drain their energy quickly and eventually lead to energy deprivation. The foxes too suffered from a similar problem. Instead of attempting to conserve energy, they would burst towards rabbits every time they spotted one (which with their large vision radius, could do so with ease). This too quickly wore down their energy. In addition, the randomness of the mutations made it difficult for vision radius to change. Oftentimes, entities with a larger vision radius would lose to an entity with a smaller vision radius simply because it got lucky.

Conclusion

While the results of this investigation may not fully answer my childish question about supersight, it at least shed some light on a possibility of the downside of such an ability. If you were able to know the whereabouts of your enemies at all times, would you be able to sleep soundly at night? It would be troubling and stressful, to say the least. While this model is obviously imperfect, it is clear to see that simulations like these are useful, and at times necessary, to understand complex natural events such as evolution.