CMPLXSYS 530
Assignment 3: Python Practice – Langton's Ant

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1. Original Model: Single Ant

After about 10,000 iterations, as expected, the ant creates the highway and proceeds to blaze its trail. However, since the boundaries are wrapped, it eventually runs into its original chaotic growth again. I continued running the simulation to see if it would get lost in the chaos or if it would somehow manage to find a new way to create a path. By about iteration 16,000, it had surprisingly created a new path, as pictured in Figure 1.

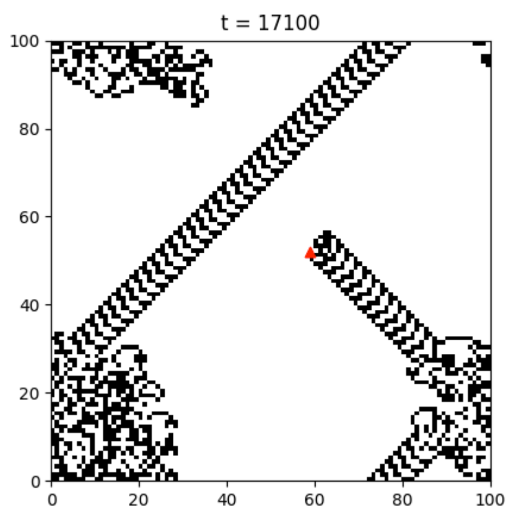


FIGURE 1. Langton's Ant building a second highway.

Once the ant ran into its first path, its new highway was once again disrupted, and it proceeded with its chaotic growth for a much longer period. It took until about iteration 57,000 before it made its way toward a third highway, as shown in Figure 2 below.

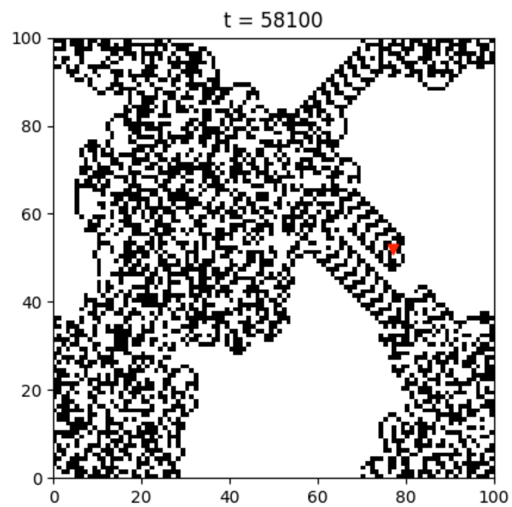


FIGURE 2. Langton's Ant building a third highway.

Surprisingly, once it reached its chaotic growth mess again, the ant quickly began making a fourth highway, proceeding 90 degrees from its previous path by iteration 59,000. Figure 3 illustrates this event.

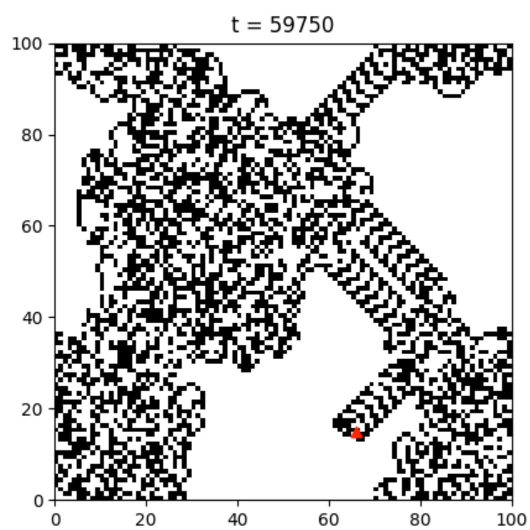


FIGURE 3. Langton's Ant quickly building a fourth highway.

A fifth highway was then built by iteration 83,000 (not pictured), but by this point, most of the environment was filled with chaotic growth. I continued running the simulation to see if anything would happen once the environment was filled with chaotic growth—perhaps the ant would start clearing some of the growth in a new pattern. However, after 180,000 iterations, nothing had happened: just lots of chaos as pictured in Figure 4. Maybe something interesting would eventually happen if the simulation ran longer, but I wasn't going to wait and find out!

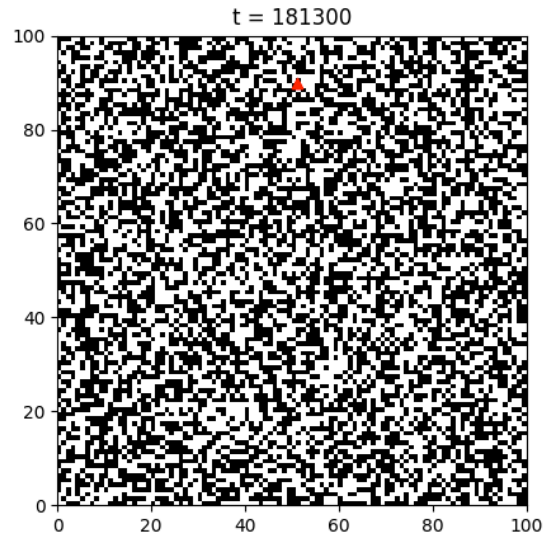


FIGURE 4. Langton's Ant has dug itself into a deep, deep hole.

2. Modified Model: Two Ants!

I modified the original model by adding a second ant that operated by the same rules. This change created some very interesting results depending on how the ants were oriented at initialization, as described below.

Initialized with the same orientation (Parallel)

To start, when the ants were initialized facing the same direction (e.g., both facing up), they operated synchronously through the first highway. Figure 5 depicts the two ants creating exactly the same pattern after 11,250 iterations.

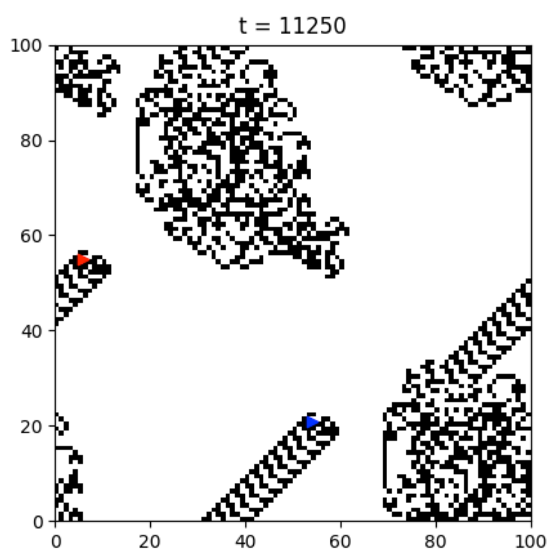


FIGURE 5. Parallel Langton's Ants behaving synchronously.

However, since the two ants did not begin with symmetric coordinates in the environment, they then ran into the chaotic growth at different points and lost their synchronous behavior. For example, after 17,000 iterations, one of the ants (blue in Figure 6 below) was able to build a new highway, whereas the other (red) ant was still stuck in the chaos:

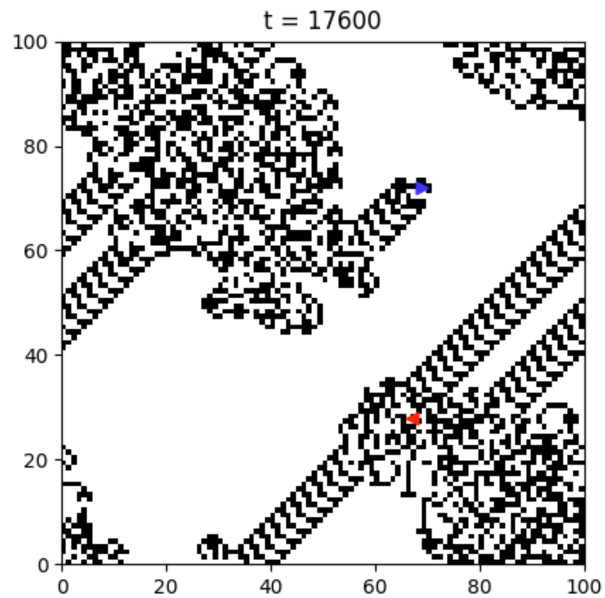


FIGURE 6. Parallel Langton's Ants no longer behaving synchronously.

A short while later by iteration 20,000, the red ant made a new path in a perpendicular direction to the blue ant's path shown in Figure 6. By iteration 34,000, the blue ant had built another highway, and by iteration 39,000, the blue ant had built yet another highway. The red ant was still lost in the chaos from its previous path, however. Thus it seems that the most interesting behavior about two ants operating in parallel is that their behavior is synchronous, at least at first. If they are not symmetrically positioned, their synced pattern will eventually be lost for good as they begin to interfere with each other.

Initialized with opposition directions (Mirrored)

When the two ants are initialized with opposition orientations (e.g., one facing up and the other facing down), their behavior becomes even more interesting. Again they move in sync with each other, but they mirror each other the entire simulation. This holds true *even after they run into each other's chaotic growth*. Figure 7 illustrates this phenomenon; here you can see that the two ants started out in such a way that when their growth collided with each other they created a butterfly-shaped pattern.

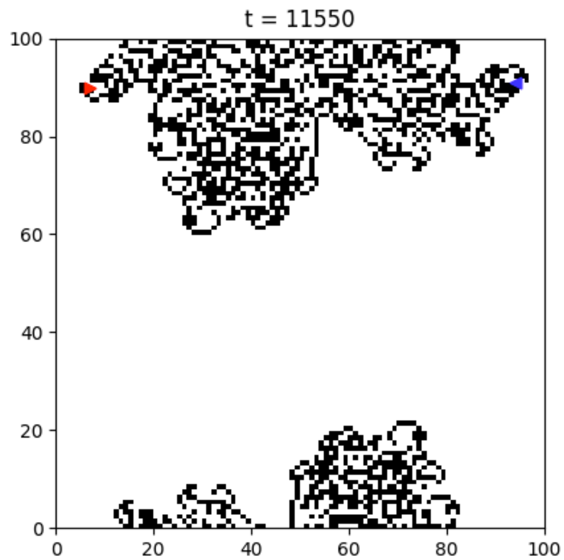
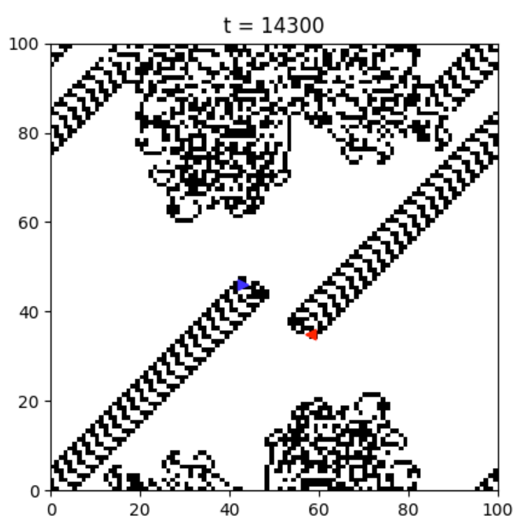


FIGURE 7. Mirrored Langton's Ants behaving in opposite sync with each other.

Again, the two ants never lose their mirrored pattern. Figures 8 and 9 below show what the simulation looks like after 14,300 iterations, and after 17,850 iterations, respectively. In Figure 8, their highways pass each other in parallel. In Figure 9, after colliding with the chaotic growth again, both ants emerge with a new highway at the exact same time.



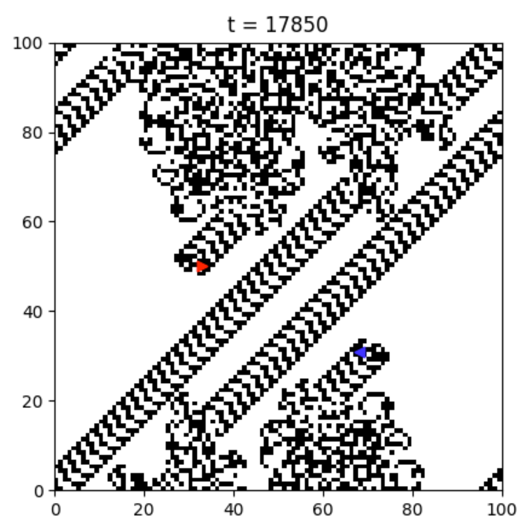


FIGURE 8 (left) and FIGURE 9 (right). Mirrored Langton's Ants continue to behave in opposite sync with each other.

I re-ran the simulation with mirrored ants again to see if perhaps I had gotten lucky and found a unique pair of ants that were placed in the right positions initially. However, this subsequent simulation with ants at new coordinates exhibited the same outcome: the two ants always mirrored each other. In short, opposite initial orientations allow for synchronous but mirrored behavior, quite possibly forever, regardless of initial positions.

<u>Initialized with perpendicular directions (Orthogonal)</u>

Finally, when the two ants are initialized in perpendicular directions (e.g., one facing down and the other facing right), I discovered two separate phenomena worth describing. The first phenomenon depended upon the ants being initialized fairly close to each other. Pretty quickly their chaotic growth combined—but instead of continuing their chaotic growth patterns, they erase each other's work! For example, Figures 10 and 11 show what has happened from iterations 1400 to 1550. The two ants' paths combine, and they reverse each other's work and start anew. This behavior continues in a cyclical pattern indefinitely, and the two ants never build any highways because they can never proceed far enough along in their pattern.

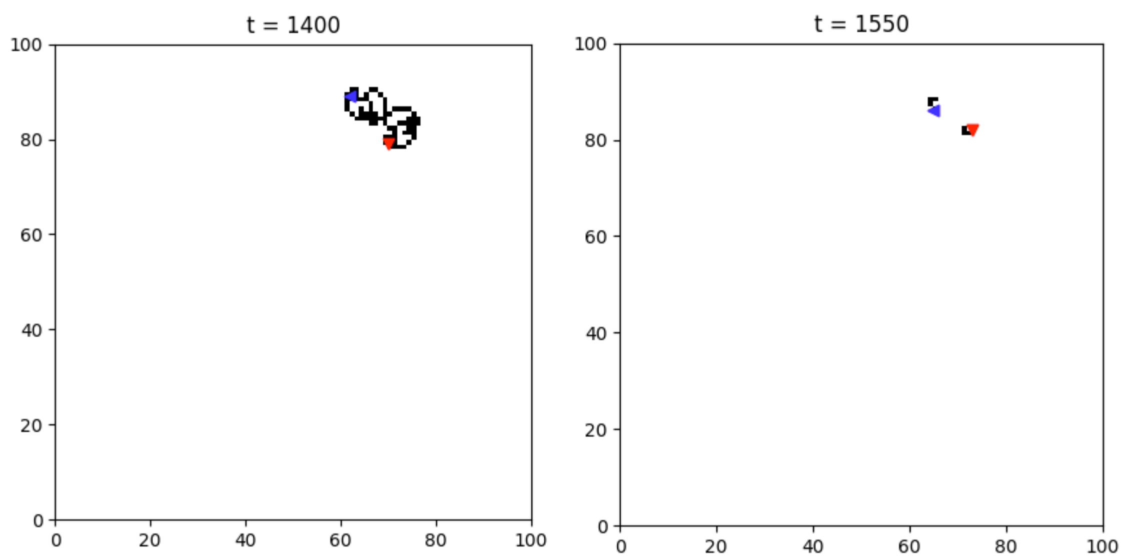


FIGURE 10 (left) and FIGURE 11 (right). Orthogonal Langton's Ants that initialize in proximity to each other will erase each other's patterns.

The second phenomenon occurred when the two ants were positioned in such a way that they combined their chaotic growth, but did not erase each other's patterns (Note: I did not pay close enough attention to whether it had to do with the precise way they were oriented, or if it had to do with coordinate positions, but it was likely one or the other of these that allowed this pattern to develop). When this happened, one of the ants started building a highway after only 4,500 iterations—less than half the time it took for the single Langton's Ant model. Figure 12 illustrates this activity. The red ant was able to use the combined patterns to forge its highway very quickly, whereas the blue ant was still work its way through the chaotic growth. The blue ant managed to begin its path after about 16,000 iterations.

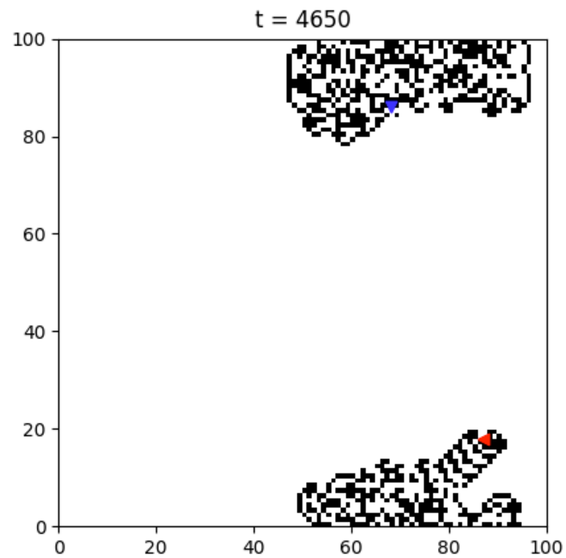
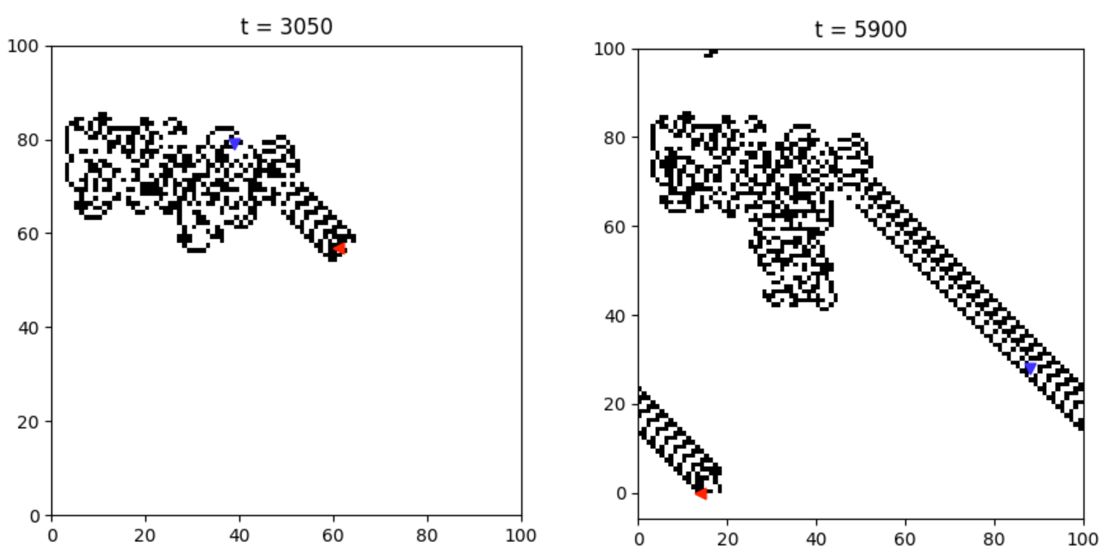


FIGURE 12. Orthogonal Langton's Ants that combined efforts.

Finally, I stumbled upon a configuration where both orthogonal phenomena occurred in the same simulation. This time, the red ant was able to start building a highway in less than 3,000 iterations. However, eventually the blue ant sped extremely quickly down the highway that the red ant had built and, once it caught up with the red ant, proceeded to erase the entire highway! By about iteration 13,000, the entire pattern had been erased and both ants started with a blank slate. The exact same behavior happened again around iteration 21,000. Thus the two ants were caught in a cycle of growth, quick highway creation, and reversal. The screenshots in Figure 13 below depict the sequence of events for this scenario.



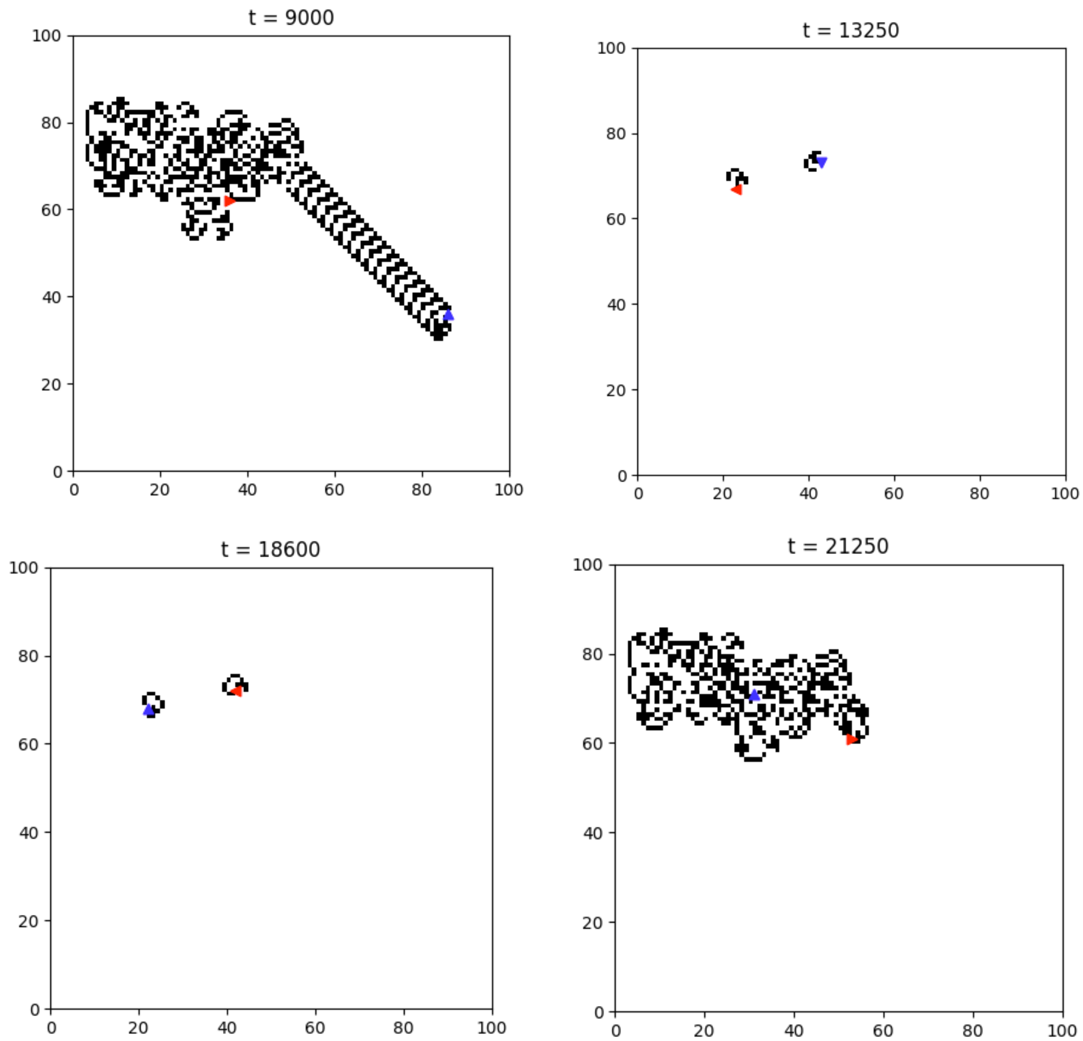


FIGURE 13. Orthogonal Langton's Ants that quickly build a highway, and then erase it before starting again. At t = 3050, the red ant has started building the highway. By t = 5900, the blue ant speeds down the highway to catch up to the red ant. At t = 9000, the blue ant is steadily erasing the highway, while the red ant works to erase the blue ant's chaotic growth. By t = 13250, the two ants have cleared the space of all growth. At t = 18600, the two ants have gone through a short cycle of growth and reversal, before starting again with the original growth pattern. Finally, at t = 21250, the red ant begins building the same highway that it had before. Note that the entire pattern is identical to the one that was originally built (see t = 3050).