Survival of the Fittest

Last week we created a genetic code for branching creatures and then used our aesthetic sense as a selection pressure to evolve them. In this lab we will model evolution using a predator prey system. We will have two breeds, hawks and doves. The doves will have two sorts of behavior. In the absence of hawks they will tend to cruise along and following simple rules may tend to flock together with other doves. When they spy a hawk, they will try a variety of measures to evade the hawk. If a dove is captured by a hawk, another dove will give birth to a new dove in order to replace it. The genetic code of the new dove will be similar to that of its parent, but with slight mutations in each of its genes. The doves will consequently face a significant selection pressure and will evolve in response. You will write the code for this model and test certain assumptions about evolution as a result. When it comes to the testing phase I encourage you to explore the different scenarios thoroughly, in order to learn what the model predicts quantitatively about how evolution responds

Flocking

While it might be interesting to write a program that gives doves the simple instructions that lead to an emergent flocking behavior, there is in fact a preexisting model that does this quite well. Open the flocking model in models library under biology. The model has a number of sliders that constitute the simple rules that govern the behavior of the birds. Read the information tab so that you understand what these simple rules are. Examine the code to see how the rules are implemented. Spend some time doing this, as you will make this program your own. Now explore the model to get a feeling for how altering the various parameters alters the nature of the flocks that form. How do you get long lines of birds? How do you get wide flocks? Can you get a V-shaped flock? What parameter values lead to random motion of the birds? Take note of these values, for future reference.

Hawks and Doves

1) At the moment you have flocking turtles, but no hawks or doves. Save the program in your CAL directory and then make two new breeds: hawks and doves. Replaces all references to `turtles` in the program with references to `doves`. You will need to replace `crt` (which is short for `create-turtles`) with `create-doves`. Create a dove shape with the shapes-editor, and set the shape equal to the name you give your dove shape.
2)   In the `setup` procedure, create 4 hawks, set their color to red and give them random positions on the screen. Give them a hawk shape.
3) In the `go` procedure ask the hawks to hunt, and then write a `hunt` procedure for the hawks. In the `hunt` procedure let hawks have a `vision-radius` and then have them head towards the nearest dove within their vision radius (if there is one). However, to make things interesting, let the hawks have a `cruise-speed` and a `hunt-speed`. When they are not hunting (ie when they see no doves, or they have just eaten a dove) they will `wiggle` at the `cruise-speed`, but when they have spotted a dove they will head toward the dove at the `hunt-speed`. I would suggest a `cruise-speed` of 0.5 units per time step and a `hunt-speed` of 2 units per time step. As an additional change, when a hawk has caught a dove, have it take a short rest before hunting again. You could do this with a boolean variable like `just-fed?`, which you set to `false` in the `setup`, set to `true` after eating, and then set to `false` again after they have had a short cruise without hunting. Test your procedure to make sure it works. You should see your flock number diminishing to zero fairly rapidly.
4) To correct for diminishing doves, write a `birth` procedure which is called if the number of doves is ever less than the initial population. Have the right number of doves give birth to new doves to maintain the population. Make the new doves move away from their parents in a new heading and have them start one patch away.

5) Now comes the important part of the program, from the standpoint of survival of the fittest. We need to give doves strategies for avoiding the hawks. Add an `escape-hawks` procedure for the doves and use it after the `flock` procedure in `go`. The `escape-hawks` procedure will be similar to the `hunt` procedure that you wrote for the hawks, except the doves will turn away form the nearest hawk within their `danger-sensing-radius`, rather than head towards it. I suggest you use the `turn-away` procedure that was written for the flocking part of the program. This procedure takes two arguments: `new-heading` and `max-turn`. For `new-heading` you would use the heading from the dove to the nearest visible hawk (`turn-away` ensures the dove turns away from this most dangerous of headings!), and `max-turn` would be an angle that represents the greatest angle they can turn in one time step you might call this angle `escape-angle` in a slider. The idea is that doves would try to turn away from the direction to the nearest hawk, but will only be able to turn a maximum of the `escape-angle` in any one step.

6) As part of your `escape-hawks` procedure. You will need to specify a `boost-speed`, which represents additional speed above the normal speed. (Note the normal movement of doves is specified at the bottom of the `flock` procedure where it says `fd 1`. Change this line to be `fd normal-speed`). We have now added several variables governing the motion of the doves: `danger-sensing-radius`, `boost-speed`, `escape-angle`, and `normal-speed`. Add sliders for these variables in your interface. Test your changes and try to choose suitable ranges for your parameter values. Use the existing parameter values as a guide. I'd suggest a `normal-speed` around 0.5 and a `boost-speed` between 0 and 1. Note that the sum of `normal-speed` and `boost-speed` should be less than whatever you choose for the hawk's `hunt-speed`, otherwise the hawks really have little hope of catching any doves! Play around with the parameter values a bit. Try to find parameter values where the birds maintain flocking behavior while they attempt to evade the hawks. You should see interesting evasion maneuvers emerge.

7) One final thing before allowing our doves to evolve. Change the interface to 25 by 25 and set the population number to 100. Also, when you create the doves, allow the doves to have any color except red (if the color is a shade of red make them white). Now run your program. You should notice that over time, the number of different colors diminishes until finally you are left with doves of just one color. Since clearly color is not a factor in the feeding habits of your hawks, and anyway all your doves have equal fitness, why is this happening? This is actually an example of a phenomenon known as genetic drift (or random drift). When two or more species have equal fitness, but compete for resources, all but one will eventually die out. This is because if one species by chance has the larger population they will on average be more likely to reproduce and hence will be more likely to increase their population. We should be mindful of this genetic drift phenomena when we are playing the survival of the fittest game that you will write next. If selection pressure is not strong enough genetic drift can be the predominant factor causing your parameters to change.

Evolution
8) Let your doves evolve. There are a total of nine variables influencing the movement of the doves, so your genetic code will be made up of the values you assign to each of these variables. For each of the dove-related sliders in your previous model (except population) make a `doves-own` variable. When you first create the doves assign each of these variables a random number (use random-float) between 0 and what you judge to be a suitable upper limit. Caution: to get realistic evolution make sure the upper limit for the two dove speeds sums to a number less than the hawk's hunt-speed. If you don't you may create super doves by hand rather than allowing them to evolve. On another note, in this lab you do not need to create a genome-list as you did in the week 5 lab, because we will be mutating the genetic code in a slightly different way this time.

9) Create sliders for the mutation rates of each of the variables in question 8, choosing a range

of values so that moderate, yet significant change in behavior can occur. Later, you will be adjusting these parameters to see how mutation rates influence evolution.

10) In your birth procedure add a line asking newly hatched turtles to mutate, and then write a mutate procedure. This mutate procedure will be slightly different from the one in the week 5 lab. Instead of only selecting one gene to mutate you will mutate all the genes in turn by adding a mutation factor. The mutation factor will be either plus or minus the mutation rate. You will need to write a separate line of code for each variable in the genetic code.

11) Create monitors to keep track each variable in the genetic code. The monitors should show the average values from all the doves.

12) It would be a good idea to measure the rate at which the doves die. Make a globals variable called `death-rate,` which you should set equal to the number of turtles who die each time step. Plot the death rate.

13) Test the model under general conditions. Allow it to run for a while – there are several changes that happen. First unfit birds are weeded out quite quickly. Then some of the gene's of the surviving birds change slowly over time. What genes change the most? Explain why? If you run the program a number of different times, with the same settings, you should be able to see species with slightly different behaviors surviving. Occasionally two species with different behaviors persist for some time together. They may have approximately equal survival rates, but for different reasons. Eventually genetic drift will eliminate one of these species. Describe the different survival strategies you observe.

14) Now experiment with mutation rates. Set mutation rates for all dove *speeds* to zero so that speed does not change. Which genes change the most now? Does the death rate decrease? Does it go down as low as in question 13?. You should notice that some of the gene's seem to keep increasing in value, yet the survival rate of the doves doesn't improve. Explain what is happening?

15) Repeat the analysis you did in each of the previous questions, but increase the number of hawks significantly. This should accelerate the selection pressure significantly. Does it alter the behavior and genetic make-up of successful doves?

16) Repeat the analysis now by setting all mutation rates high. Does this have an affect on the overall fitness? Make quantitative comparisons. How about when mutation rates are low?

17) Replace the flocking command in `go`, with a simple `wiggle` at `normal-speed` command. Return mutation rates to the values in 13. Allow the system to evolve. What do you notice about the survival rates of the doves. Is flocking a good survival strategy? Do you think your answer would be different if you changed the number of hawks to a lower number?

Extension for the Curious

18) Here are a couple of suggested changes you may want to try out.
   a) Let Hawks evolve too. In order to evolve we have to let them die. Give hawks an initial energy, a metabolism, and an increase in energy from eating doves. Hawks die if their energy reaches zero. (you could also use this variable to control the resting time. For example, perhaps they gain 20 units of energy when they eat a dove and start hunting for another one when their energy has dropped to 15). If a hawk dies, let another hawk give birth to a new but slightly mutated hawk. You will need to write a hawk-mutate procedure and define suitable gene variables for the hawks. Have fun. Do you observe any arms-race type behavior in the evolution of hawks and doves?
   b) To allow for two species of doves to evolve you could create a larger green area on the screen representing a forest. Allow the color of the doves to be a genetic variable, and also allow doves to optionally head towards or away from green patches if they can see them. To apply selection pressure make it difficult for hawks to see doves with shades of green who are on green trees. Does this enhancement lead to speciation, or just a bunch of green doves who like to sit on trees?

19) Before submitting your NetLogo program write comments for all your procedures explaining what each "non obvious" line does.