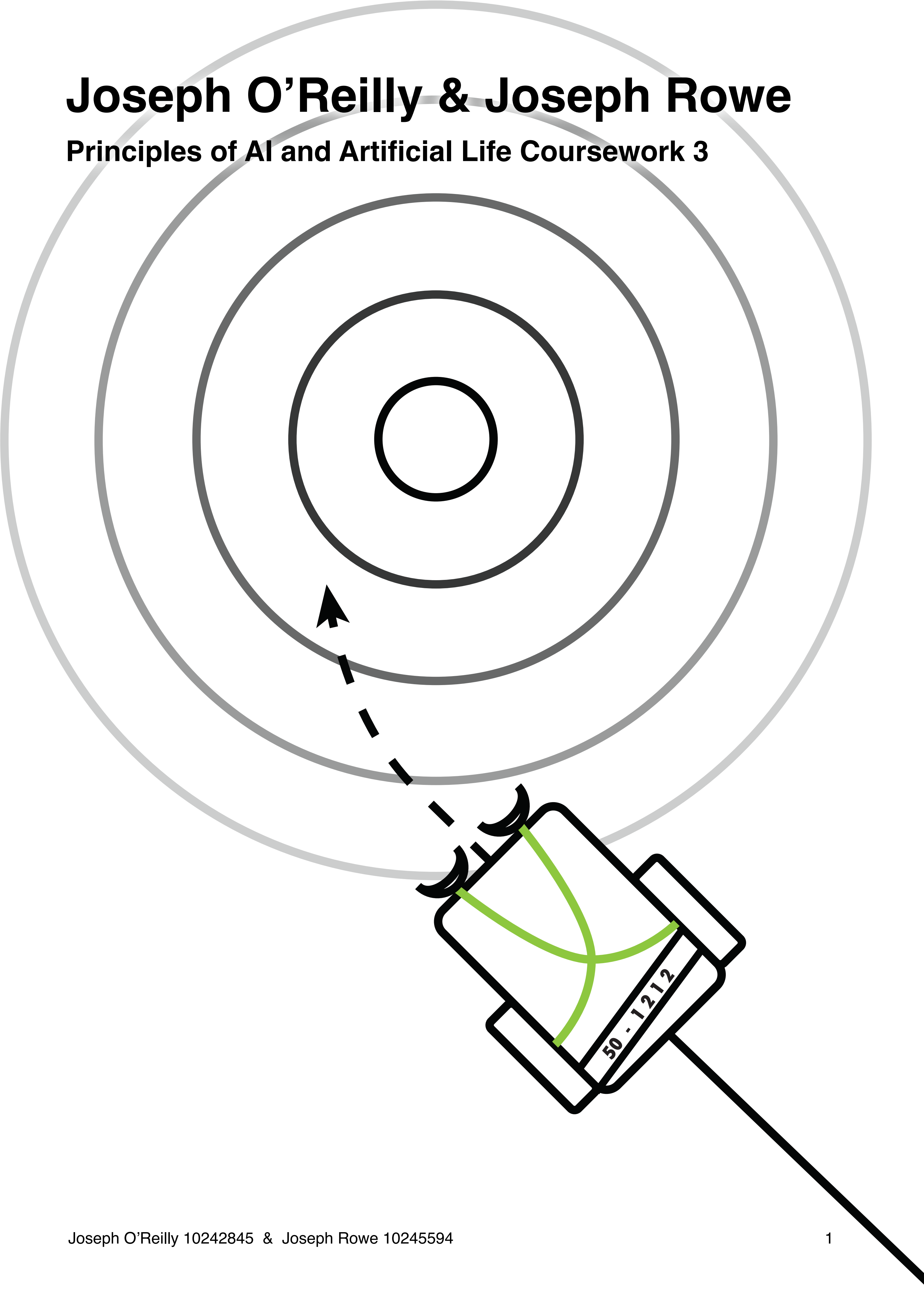
Joseph O'Reilly & Joseph Rowe

Principles of AI and Artificial Life Coursework 3



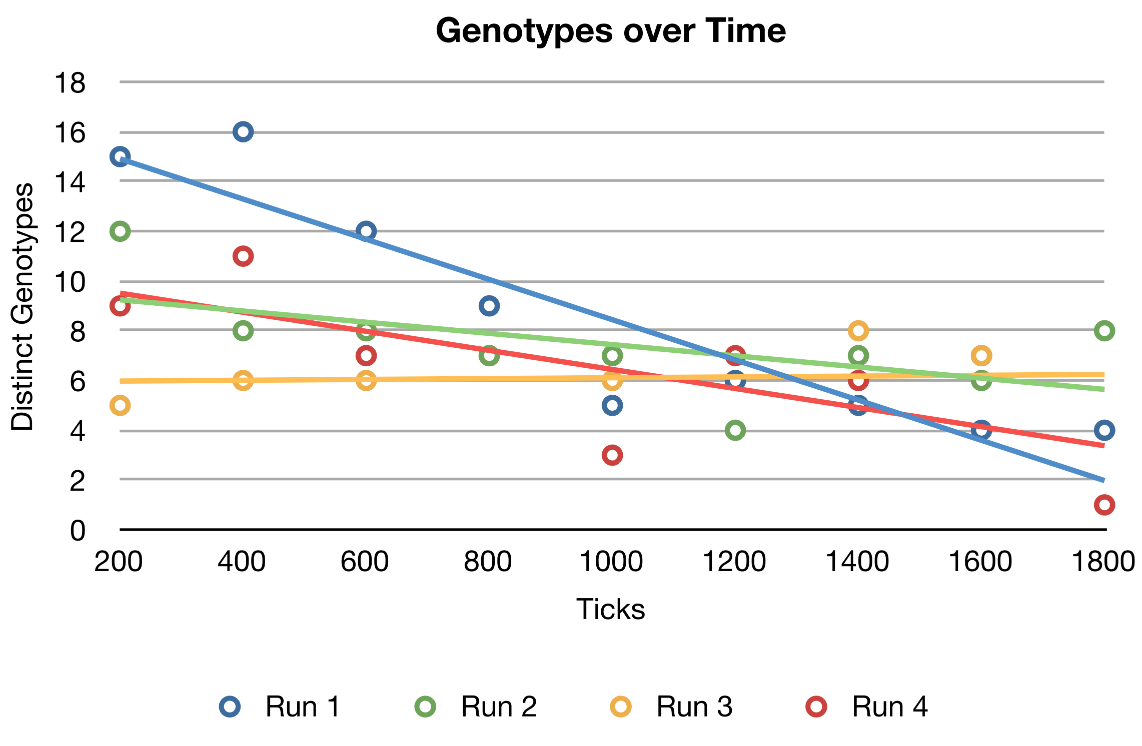
Section A

1. A Basic Population Sample

The results of our experiments show that when using the default values, the number of distinct genotypes is at first high, showing variety in the different “genotypes” within the population, however, as the genotypes which are not well equipped to move towards the light fail to increase their energy and die, and the genotypes which are well equipped to move towards the light increase their energy and are able to reproduce, the number of distinct genotypes decreases, leaving only the strongest genotypes in the population.

A factor affecting this is the mutation rate, which at the default setting of 1.0 allows for constant slight variations in the distinct genotypes, as strong genotypes may spawn a weaker genotype, therefore enabling weaker genotypes to exist within the population at any stage in the testing.

The graph below shows our findings when running the simulation for 1800 ticks using the default settings (target population = 200, mutation rate = 1%, reproduction threshold = 5.0, reproduction probability = 5%, move-lights off, temperature sensitivity off):

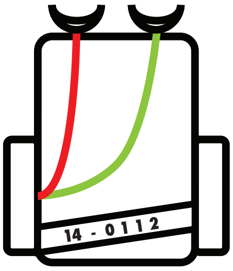


This graph shows that at the beginning of the population, there were an average of 10.25 distinct genotypes, whereas the simulations ended with an average of only 4.25 distinct genotypes.

Below are illustrations and explanations of the dominant genotypes for each run of the simulation:

Run 1

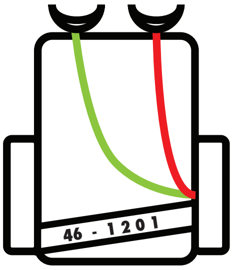
The dominant genotype for this run was 14, with a structure of [0 1 1 2]



This genotypes left sensor inhibits its left motor, and its right sensor excites its left motor. This causes turtles of this genotype to pivot towards the light if it is on its right, and pivot away from the light if the source is on its left, as a result, a turtle near enough to a light source on the right will turn towards it until its left sensor becomes stimulated, at which point it will turn away from the light, then repeating this cycle of behaviour. This means that this genotype is able to stay on top of and follow a light source, thus constantly increasing its energy and enabling it to reproduce, however, if a turtle of this genotype does not spawn near enough to a light source, it would be unable to seek the light source out, and so would not survive in the environment.

Run 2

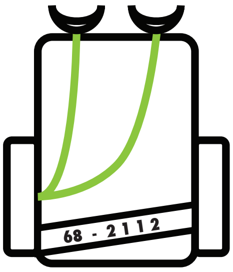
The dominant genotype for this run was 46, with a structure of [1 2 0 1]



This genotype is also well equipped for staying on a light source in much the same way as genotype 14 (above) however, the sensor to motor connections are reverse, so the right sensor inhibits the right motor, and the left sensor excites the right motor. This means that although the connections are reversed, this genotype behaves in the same way, only turning in the opposite direction.

Run 3

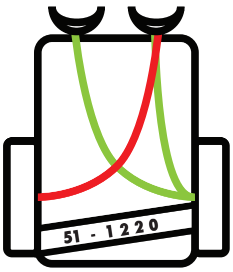
The dominant genotype for this run was 68, with a structure of [2 1 1 2]



This genotype's internal structure causes its right sensor to excite its left motor, and its left sensor to also excite its left motor. This means that if a light source exists on its right, it will turn towards it, however, if a light source exists on its left it will turn away from it. This has the effect that when turning towards a light on its right, the left sensor will become stimulated, causing the turtle to turn even quicker, thus pirouetting around the light source, enabling the turtle to also follow a light if it moves away.

Run 4

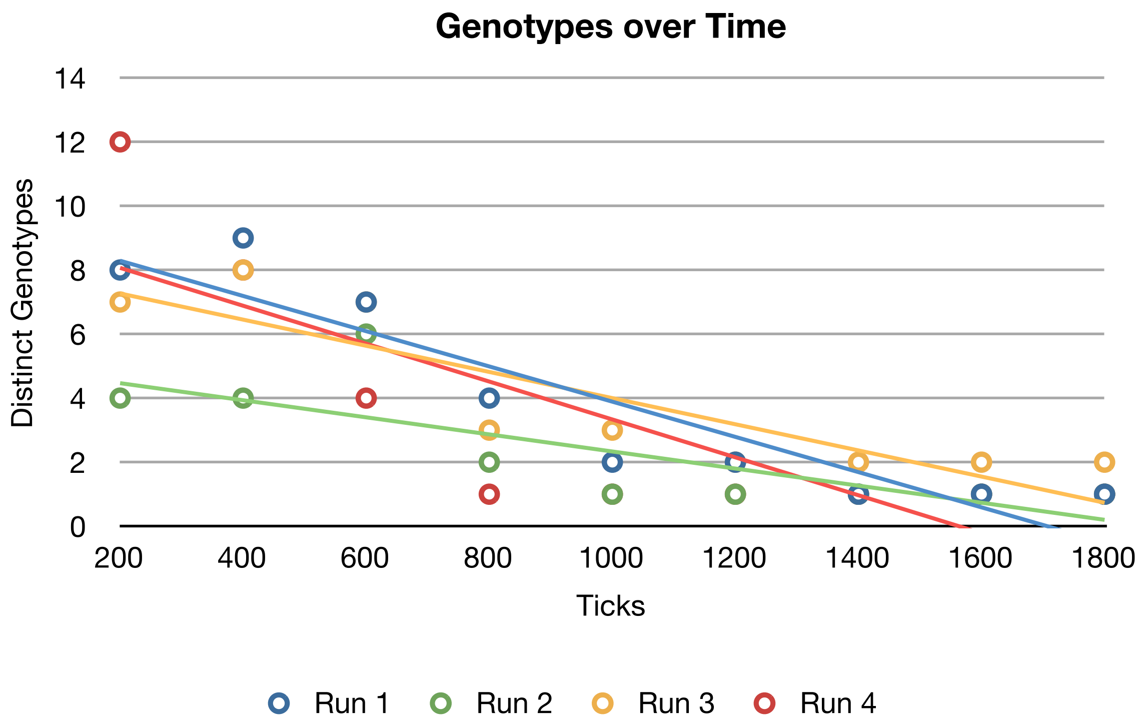
The dominant genotype for this run was 51, with a structure of [1 2 2 0]



This genotype has a slightly more complex internal structure than the previous dominant genotypes, as it has three connections, as opposed to two. The result of This genotype's internal structure is that the turtles right motor receives twice as much power as default, and its left motor receives half as much as default, causing turtles of this genotype to spin on the spot. When a light source moves nearby (or the turtle spawns near a light source), its sensors doubly excite its right motor, and inhibit its left motor, causing the turtle to spin quickly towards the light source. Once receiving maximum light, the turtle will spin around following the light. This means that if this genotype is lucky enough to find itself within a close enough proximity to a light source, it will remain on the light source increasing its energy (and with it, its ability to reproduce), however, if this turtle is not spawned near a light source (or with a moving light that may come close to it), then this genotype will not survive.

2. ZERO MUTATION RATE AFTER 600 TICKS

The graph below shows the results when setting the mutation rate to 0 after 600 ticks.

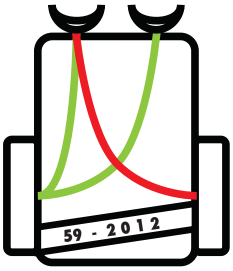


By setting the mutation rate to 0 there is no chance for the genotypes in the population to spawn a different genotype which may be better equipped to survive in the environment. As shown in the graph above, after 600 ticks the number of distinct genotypes drops sharply, as the only genotypes with a chance of survival are the ones currently in the population. From 0 to 600 ticks, however, the population was able to spawn different genotypes, meaning that there is a window of opportunity for the initial population to develop to a stronger overall population as weaker genotypes die off, enabling stronger ones to take over. This window of opportunity was 1/3rd of the overall simulation time, therefore stronger genotypes have only 1/3rd of the time to develop, as a result, the dominant genotype at the end of each run is not indicative of the genotype best equipped to survive in the environment overall, but rather an indication of the genotype best equipped to survive in the environment from the population at the point when mutation was set to 0.

Below are details of the dominant genotype for each run, and a brief explanation of its behaviour.

Run 1

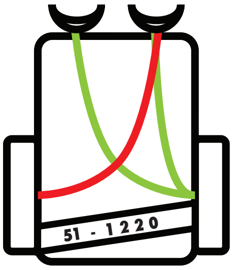
The most dominant genotype for this run was 59, with a structure of [2 0 1 2]



This genotype is a reversal of genotype 51, as mentioned above, and will behave the same way, only turning in the reverse direction.

Run 2

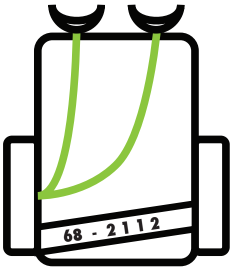
The most dominant genotype for this run was 51, with a structure of [1 2 2 0]



This genotype is mentioned above.

Run 3

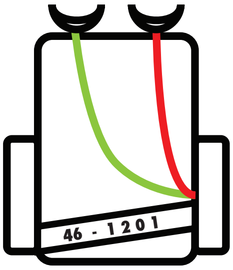
The most dominant genotype for this run was 68, with a structure of [2 1 1 2]



This genotype is mentioned above.

Run 4

The most dominant genotype for this run was 46, with a structure of [1 2 0 1]



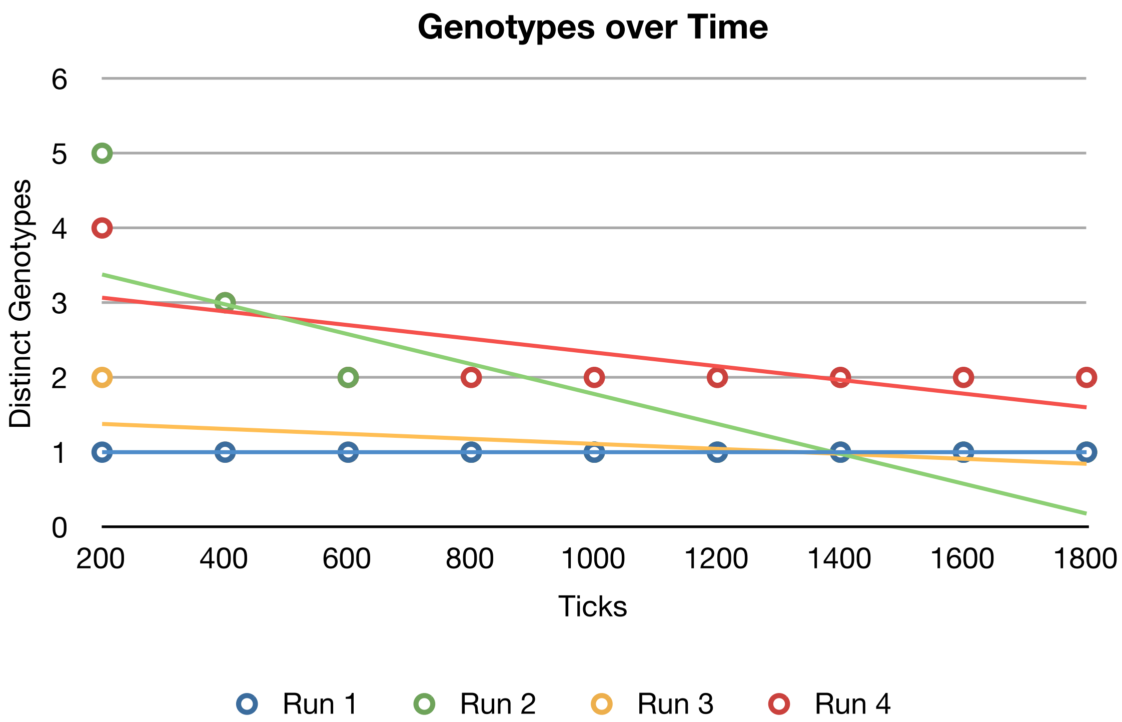
This genotype behaves quite differently to the others, in that it does not seek light, nor avoid it, nor follow light. Instead, turtles of this genotype simply remain on the spot and watch light as it passes by them. Due to its internal structure, if a light source moves past it on the right, the turtle's right motor will be inhibited, thus causing it to face to the right, and if a light source moves past it on the left, the turtle's right motor will be excited, causing it to face to the left.

This genotype does not display any behaviour indicative of an ability to seek out and make use of a light source, and so it seems to have been the dominant genotype in this run purely by chance, as there was only one genotype left at the end.

It is interesting to note that genotypes 51, 46 and 68 were dominant in these results as well as in the previous results, indicating that they are a much stronger genotype in this environment overall, whereas genotype 46 was only the strongest out of the population when mutation was set to 0.

3. ZERO MUTATION RATE

The graph below shows the results when running the simulation with a mutation rate of 0 from the beginning.

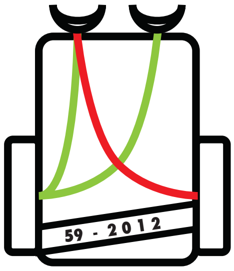


The results from these simulations show that when the mutation rate is set to 0 from the beginning, the variation in genotypes is much more limited which causes the number of different genotypes to drop sharply. This is because the populations are randomly generated, and if these randomly generated populations do not contain a fit genotype to begin with, there is no chance of one being spawned by a less fit genotype. The result of this is that after the first 200 ticks, the number of distinct genotypes is significantly reduced. At this point the remaining genotypes will either be able to survive in the environment and the population of these genotypes will continue to spawn, or the genotypes will be unable to adequately survive and will die out. Crucially, when there is no chance of mutation, the resulting dominant genotype is only representative of the fittest genotype from the initial population, not representative of the genotype best suited to survive in the environment.

Below are details of the dominant genotype for each run, and a brief explanation of its behaviour.

Run 1

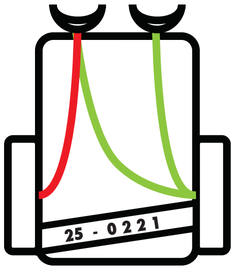
The most dominant genotype for this run was 59, with a structure of [2 0 1 2]



This genotype is mentioned above.

Run 2

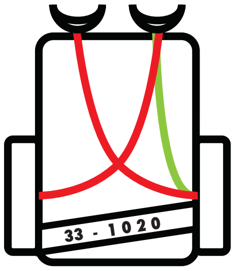
The most dominant genotype for this run was 25, with a structure of [0 2 2 1]



This genotype's internal structure causes the left sensor to inhibit the left motor and excite the right while the the right sensor only excites the right motor. This causes turtles of this genotype to spin anti-clockwise when given sufficient light. When in close proximity to a light source turtles of this genotype give the impression of following the light while actually merely spawning on top of it repeatedly.

Run 3

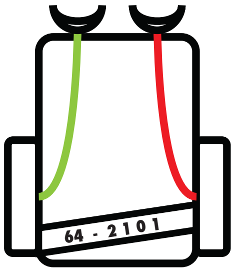
The most dominant genotype for this run was 33, with a structure of [1 0 2 0]



This genotype's internal structure causes the left sensor to inhibit the right motor and the right sensor to excite the right motor while inhibiting the left. As a result, turtles of this genotype will turn anti-clockwise towards a light source and move backwards slowly. Interestingly this causes turtles of this genotype within a close enough proximity to a light source to move in wide spirals decreasing more and more as they near the centre, at which point they remain spinning in tight circles around the centre.

Run 4

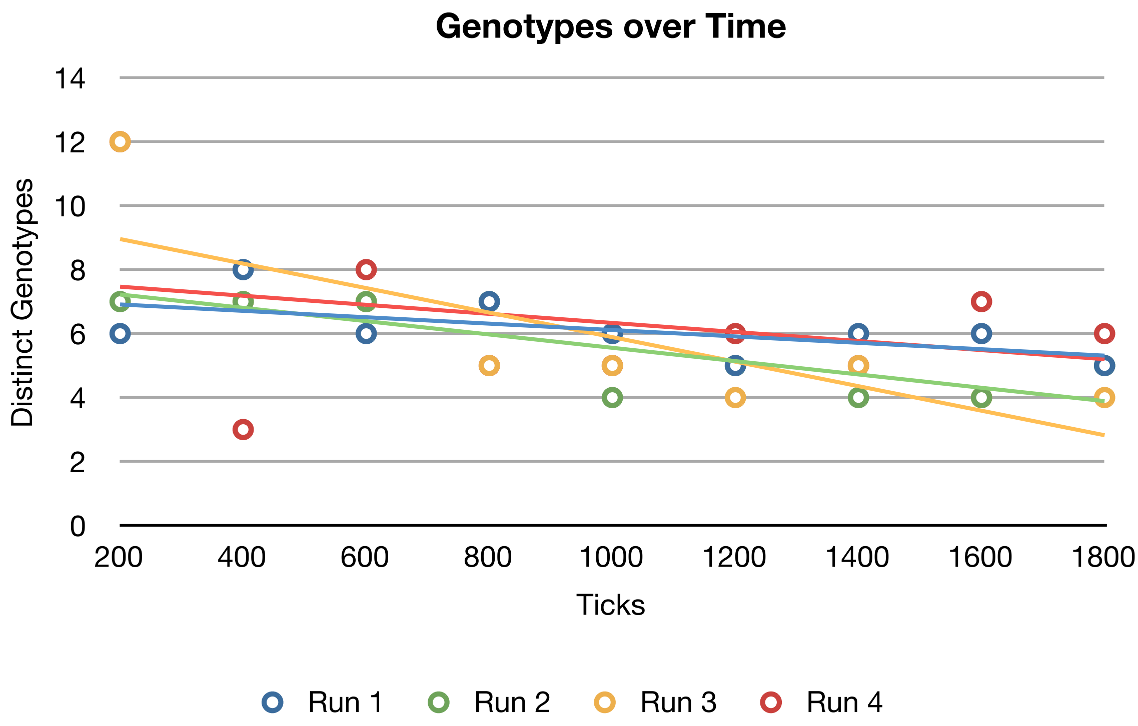
The most dominant genotype for this run was 64, with a structure of [2 1 0 1]



This genotype's internal structure causes the left sensor to excite the left motor and the right sensor to inhibit the right motor. When in a close enough proximity to a light source turtles of this genotype begin to spin anti-clockwise almost orbiting the light source, at this point their energy is sufficient to enable reproduction allowing a small cluster to form around the light source. Similarly to genotype 25 this gives the illusion of following the light while actually continuously spawning within the centre of the light source.

4. MOVING LIGHTS

The graph below shows the effect of running the simulation with the light moving.



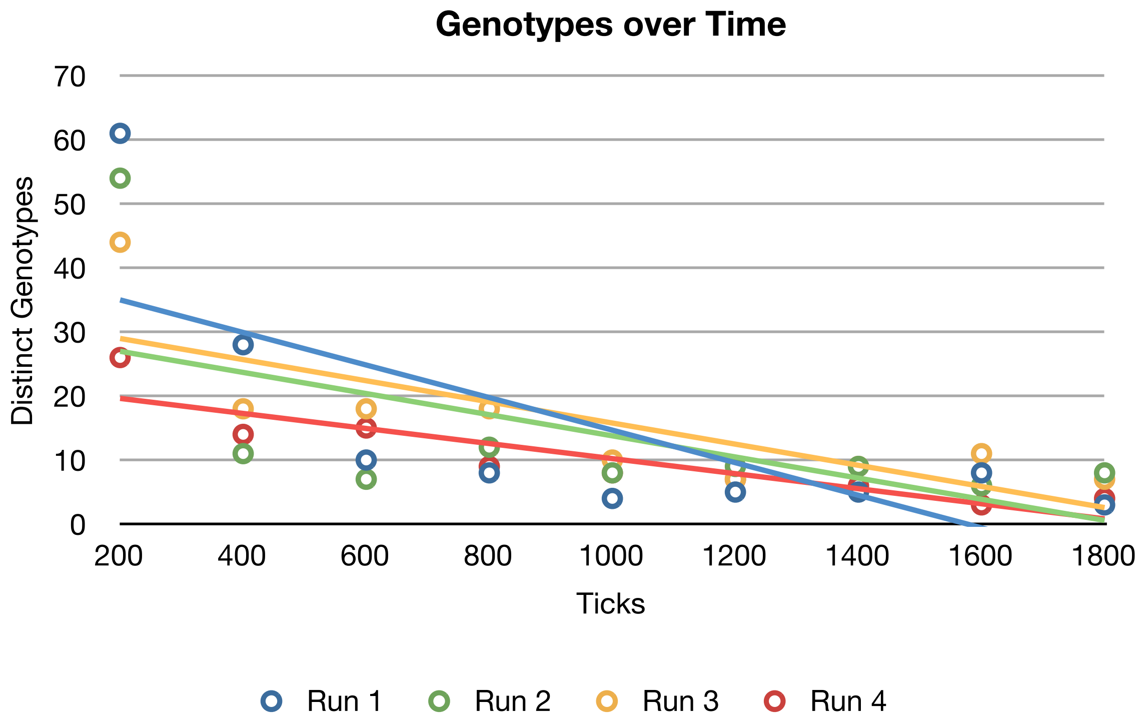
This shows a more stable population difference overall. The reason for this seems to be that due to the light moving across the world, genotypes which do not actively seek out the light may find themselves receiving energy purely by chance. For example, genotype 14 is unable to seek out light, but if it spawns near enough to light it is able to move in to the light and remain there. The effect of lights moving means that inherently flawed genotypes are able to survive more easily, thus resulting in less drastic changes in the number of distinct populations.

The dominant genotypes for these experiments were 46, 20, 14 and 59, which were all observed previously and described above. It is interesting to note that all of these genotypes exhibit a spinning behaviour.

5. TEMPERATURE SENSITIVE SWITCHED ON

Turning on temperature sensitivity means that turtles in the direct center of a light source will be burned to death. The affect of this is that those turtles which previous succeeded by spinning in a light source will be killed off, and those that stayed close to the periphery of the light source will be the most successful.

Below is a graph showing our results of turning on temperature sensitivity.



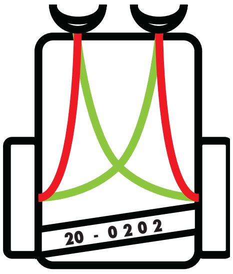
After 200 ticks there was an average of 46.25 distinct populations, however, 200 ticks later this drops to an average of 17.75, finally resulting in an average of 5.5 distinct populations.

Initially a large amount of the population that had spawned on or too close to a light source will be killed, leaving a large void which will be filled. As there will be no dominant genotype at this stage, the remaining population will reproduce to compensate resulting in a large variety of added genotypes. This genotype's internal structureThis also indicates that turning temperature sensitivity on culls those genotypes which previously excelled in surviving by staying within the lights.

The most dominant genotypes observed after each run are shown below:

Run 1

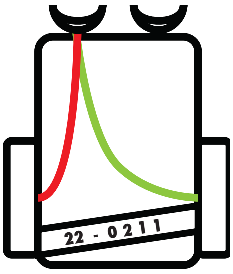
The most dominant genotype for this run was 20, with a structure of [0 2 0 2]



The internal structure of this genotype results in the left sensor inhibiting the left motor and exciting the right motor, while the right sensor inhibits the right motor and excites the left motor. This causes turtles of this genotype to face the light where it remains and spawns giving the impression of following the light while only spawning on top of it repeatedly.

Run 2

The most dominant genotype for this run was 22, with a structure of [0 2 1 1]



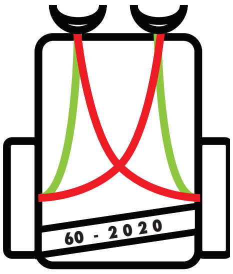
The internal structure of this genotype results in the left sensor inhibiting the left motor and exciting the right motor (as observed in genotype 20), however, there are no connections made from the right sensor. This causes turtles of this genotype to behave in the same was a 20, however it will only ever spin anti-clockwise.

Run 3

The most dominant genotype for this run was 20 again, with a structure of [0 2 0 2]

Run 4

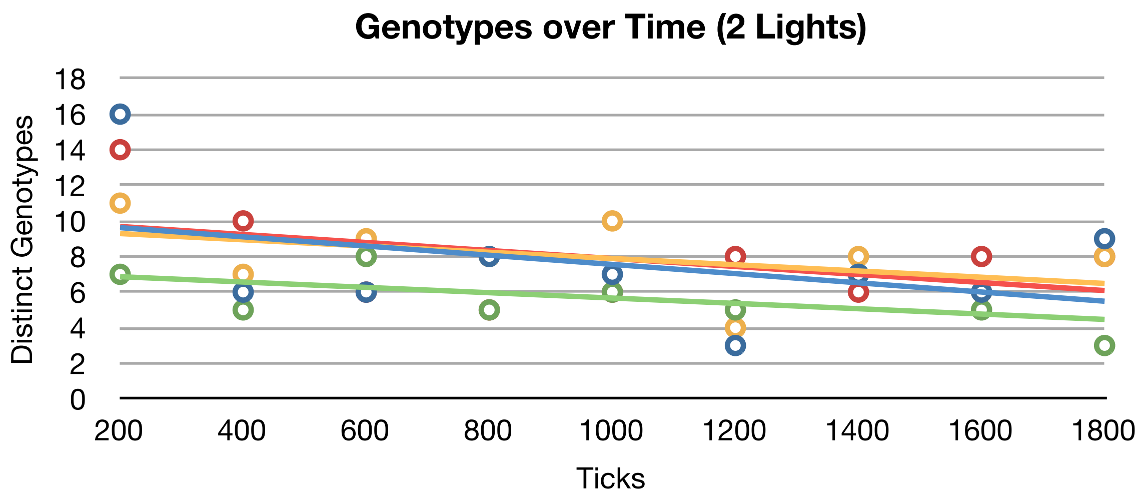
The most dominant genotype for this run was 60, with a structure of [2 0 2 0]

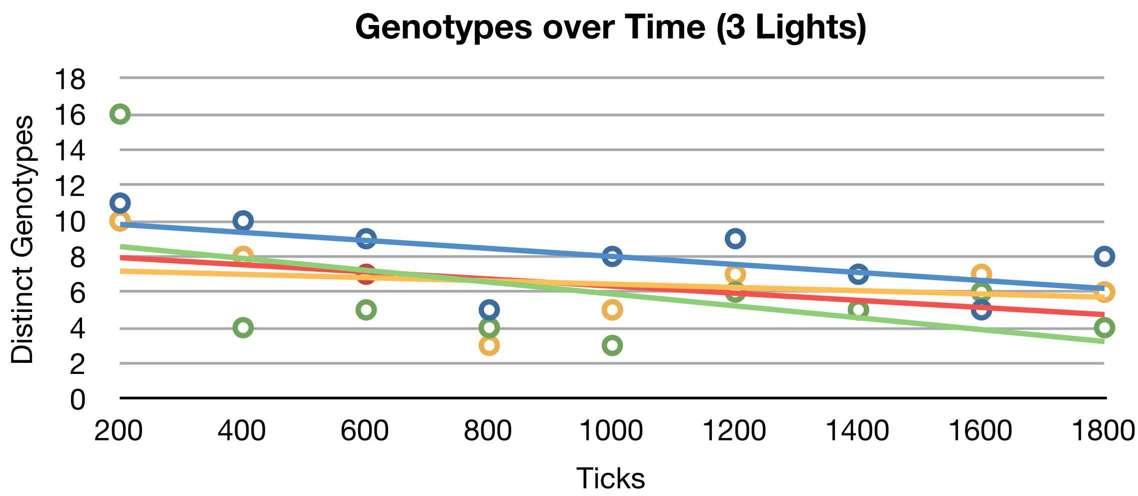


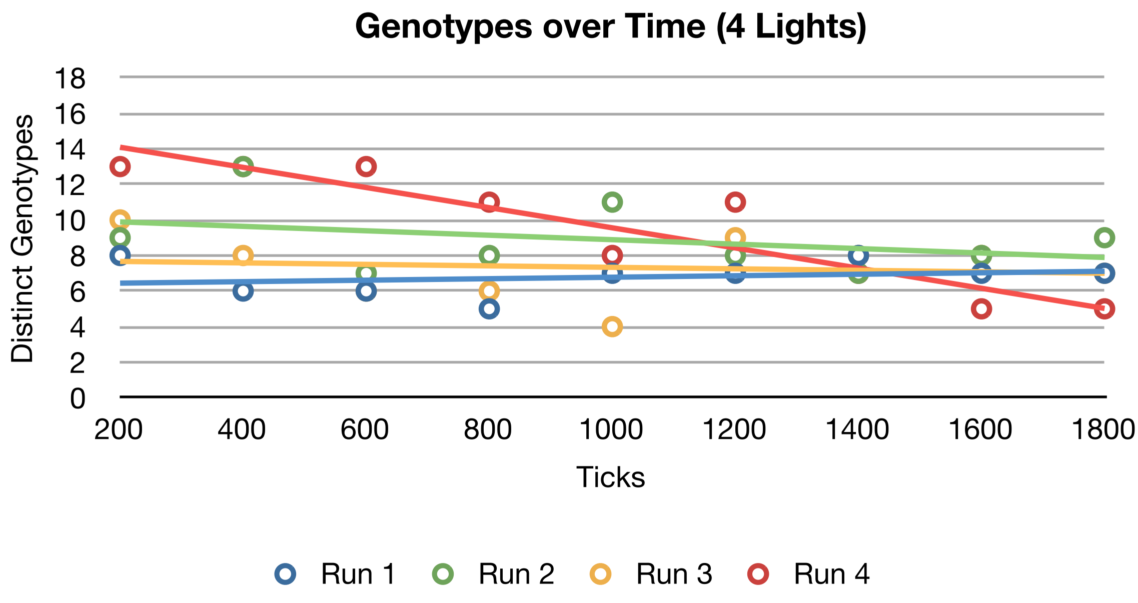
This genotype's internal structure causes the left sensor to excite the left motor and inhibit the right motor, while the right sensor excites the right motor and inhibits the left. This is a reversal of genotype 20, and will exhibit the same behaviour, only with reversed directions.

6. MULTIPLE STATIONARY LIGHTS

The graphs below show the effect that running the simulation with multiple (stationary) lights has on the number of distinct genotypes observed.



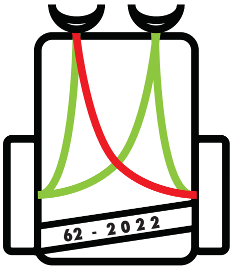




This shows that with multiple lights the number of distinct genotypes becomes even more stable than with moving lights. The reason for this is that by adding more lights, more of the world becomes “goal areas”, thereby enabling more of the populations to increase their energy and reproduce. In essence, this makes the environment much more easy for the turtles to survive in, thus “survival of the fittest” does not require a particularly “fit” genotype to begin with. As can be seen from the above graphs, the average bars stay pretty much straight, demonstrating the stability of the distinct genotype variations.

The dominant genotypes here were 14, 46, 68, 51, 52, 62 and 67 - of these 14, 46, 68 and 51 have all been previously observed, 52 is mirror of 68, while 62 and 67 are described below.

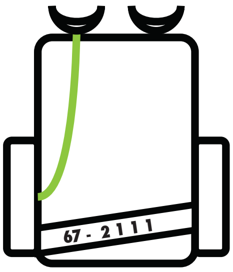
Genotype 62



This genotype’s internal structure ([2 0 2 2]) causes the left sensor to excite the left motor and inhibit the right motor, while the right sensor excites the left motor.

This causes turtles of this genotype to spin clockwise in wide circles. When in close proximity to light sources they begin to orbit it until their energy levels facilitate reproduction, enabling a cluster of turtles of this genotype to orbit and follow the light source repeating the reproduction process.

Genotype 67



This genotype’s internal structure ([2 1 1 1]) causes the left sensor to excite the left motor. Turtles of this genotype behave in a very similar fashion to those of genotype 62. When in close proximity to a light source they spin clockwise in very tight circles until they reach the centre of the light source where they orbit, increase their energy levels and reproduce.

WRAP UP

The results of these experiments are quite predictable with regards to how the number of distinct genotypes will change over time, and also in some respects with regards to the properties of the dominant genotypes at the end of a simulation.

The number of different genotypes in the population will always gradually decrease as weaker genotypes die off, and fitter genotypes reproduce, until eventually a core group of genotypes well suited to achieving the environments goal will remain. The properties of these dominant groups are generally an ability to spin around within a light source, ensuring that they are able to absorb as much energy as possible. This spinning behaviour satisfies the requirements of the turtles aim of gaining enough energy to reproduce very nicely, as once within close enough proximity to a light source, the turtles are able to remain there. Turtles with more aggressive behaviour are well adapted to finding a light source, however, they then move too fast once within the light source and exit through the other side. Spinning turtles do not have this flaw, and so are able to ensure their dominance by constantly gaining energy and reproducing.

Another benefit of this spinning behaviour is that even if the turtles are not able to actively seek light, they are afforded the opportunity of moving in to the light by virtue of mutating from another genotype near to a light source, or by virtue of a light moving towards it.

SECTION B

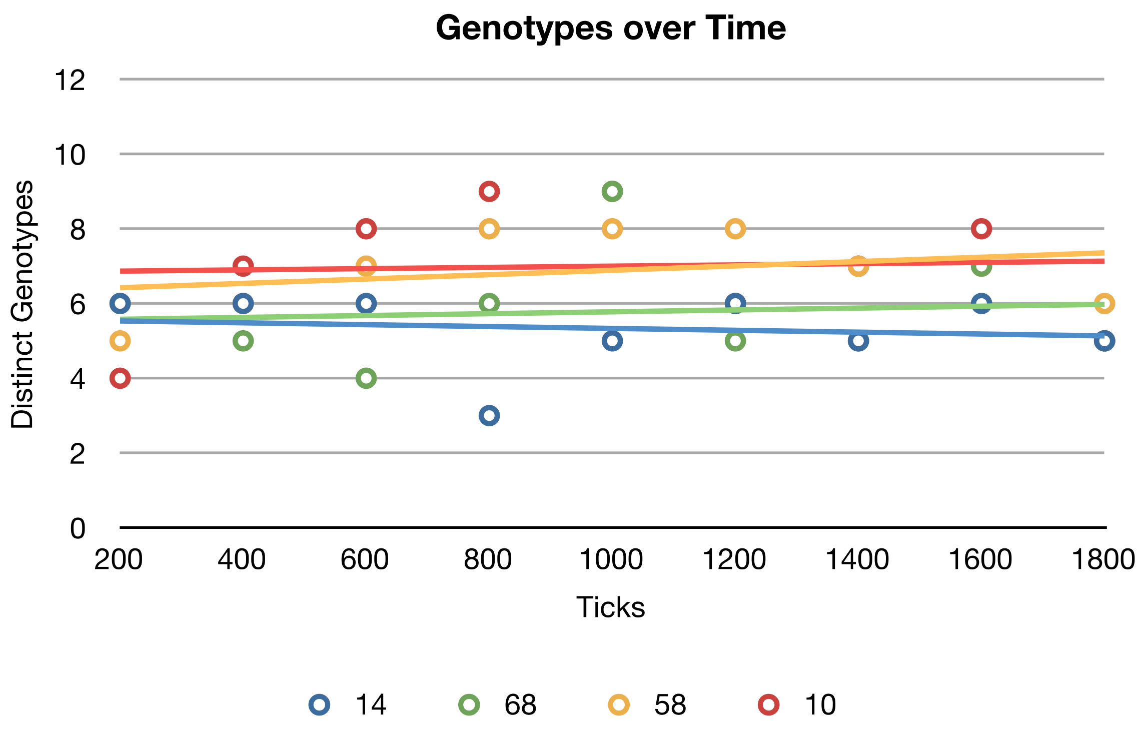
INITIAL POPULATION ONLY CONTAINS ONE GENOTYPE

USE A STRONG AND WEAK GENOTYPE

For this section we modified the program code so that when an option of 'user-selected-gene' was turned on, instead of the population consisting of a variety of randomly generated genotypes, the user was able to set four option boxes to contain a 0, 1 or 2, which would then be used as the input to define the specific genotype. We also added a display to show the base-10 identifier of the genotype that had been chosen.

The graph below shows results for running the simulation using default parameters, however, instead of beginning with a random selection of genotypes, the entire population is set to a user specified genotype. We decided to use genotypes that were observed to be the most commonly recurring dominant genotypes from our previous experiments – we also chose to use genotype 10, which avoided light, to observe the effects of beginning the population with a genotype that was not well suited to the environment goal. (We selected genotype 10 as it was observed previously in our data gathering as a genotype which would often spawn, survive for a brief period, and die)

The graph below shows the results of these tests:



This graph clearly shows that when the initial genotype is user defined, the difference in distinct genotypes remains much more stable on average. This is because there is only one genotype to begin with from which mutations can occur, whereas normally there is a large selection of varied genotypes, all of which are able to mutate and reproduce, further increasing the diversity of the population.

We also found that when the initial genotype was set to be a commonly dominant genotype, it was able to beat off all competition and remain as the dominant genotype by the end of the run. In the case of genotypes 14 and 68, their population remained at over 95% of the overall population throughout the run, with the other genotypes filling the remaining portion of the population.

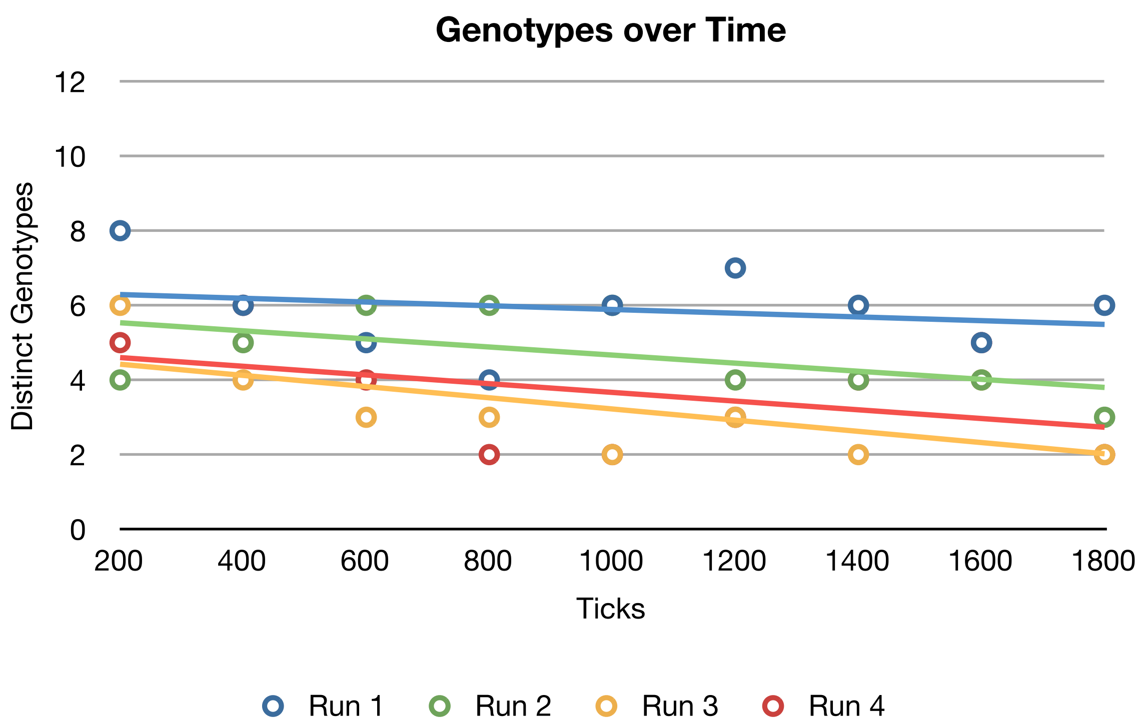
In the case of genotype 58, by the end of the run genotype 14 had overtaken it as the dominant genotype, and in the case of genotype 10, it was overtaken very quickly by genotype 52. This shows that when the population is initiated using the strongest genotypes, they are able to maintain their position of dominance, however, when the population is initiated to a weaker genotype, they will very easily be replaced by a more dominant genotype. Before we ran this experiment we were unaware that genotype 14 was “fitter” than genotype 58, thus initiating the population to a user defined genotype proved to be a very good way of determining just how fit a specific genotype is, and whether or not it can be superseded by another genotype.

SECTION C

FORCING CONNECTIONS

For this section we modified the code so that instead of the simulation selecting a random genotype between 0 and 2, it instead had to choose from a restricted set of only 0 and 2. We also had to modify the mutation procedure to prevent a genotype with no connection from spawning.

The graph below shows the affect of restricting the initial population to only genotypes with excitatory or inhibitory connections:



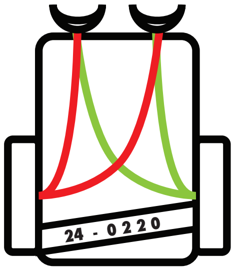
As would be expected, the initial population is greatly reduced as the total population can now only have a total of 16 distinct genotypes, therefore, the fittest genotype observed at the end of each run was the fittest from a very restricted set. Also shown is that the overall difference in distinct genotypes is much less changeable, causing a much smoother average distinct genotype line.

The dominant genotypes for this experiment are shown below:

Run 1

The most dominant genotype for this run was 24 again, with a structure of [0 2 2 0]

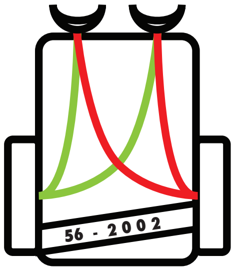
This structure causes turtles of this genotype to turn away from a light source on its right or left, resulting in it moving in tight spinning turns. Similar to other spinning genotypes, when receiving maximum stimulation, turtles of this genotype are able to stay inside and follow a light source.



Run 2

The most dominant genotype for this run was 56, with a structure of [2 0 0 2]

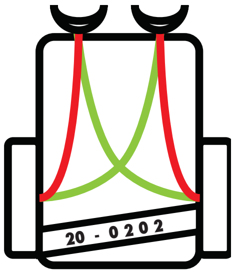
This genotype is a reversal of genotype 24, and will work in the same way.



Run 3 & 4

The most dominant genotype was 20, with a structure of [0 2 0 2]

This genotype is mentioned previously in this paper.



Note

It is interesting to note that the dominant genotypes from these experiments exhibit the same behaviours as the dominant genotypes from the previous experiments, only with forced inhibitory or excitatory connections from both sensors to both motors.

SECTION D

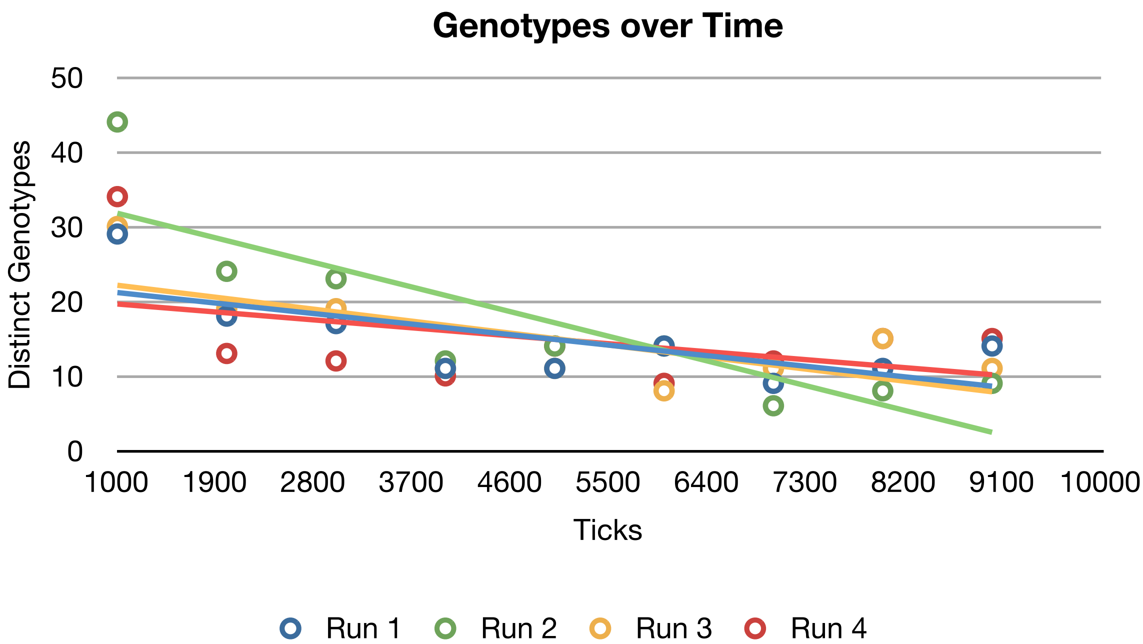
MAKING TURTLES AVOID THE LIGHT

For this section we modified the code so that turtles lost energy based on their temperature rather than gaining it, we rewarded movement with a small energy increase to compensate for the effect of light reducing energy levels.

We observed a few runs of this and noticed that when there was one stationary light, the turtles would simply remain in dark areas reproducing, therefore, we decided to run the experiment with four moving lights to cultivate a more challenging environment. We chose to use moving lights rather than a stationary light as we felt this would produce a more accurate simulation of something that needed to be “avoided”, rather than something which the turtles could simply not go near. Our hope was that this would result in the dominant genotype being representative of the fittest genotype when faced with the goal of avoiding light, as opposed to representing a genotype which was able to simply remain stationary and reproduce.

We also noted that due to this new goal, there was no dominant genotype established by 1800 ticks, and so decided to run these experiments at 10,000 ticks, recording details of the number of distinct genotypes every 1000 ticks.

Below is a graph of our findings when the turtles were tasked with avoiding the light:



This graph shows much the same as in previous tests with the population steadily decreasing, however spread over a much longer period. This indicates that the effect on the populations is much the same however the time taken for the effects to become apparent is far greater.

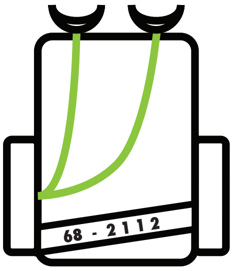
During these experiments, the turtles could only gain sufficient energy to reproduce if they were far enough away from a light source, therefore turtles that spawned in these dark locations would remain there happily until a light source passed by and disrupted them, at which point they would be killed off, and a group of turtles in another dark area's population would then increase.

Due to the set up of the environment, hot spots for reproduction were dark corners (much like real life) and the inhabitants of these dark corners would happily remain there, reproducing, until such time as they were discovered (much like real life) – to resolve this would have required the light source to wrap around the world, however, it is likely that the results would not be dramatically different, as the same process of only turtles in dark areas being able to reproduce would continue.

The dominant genotypes from these experiments are shown below:

Run 1

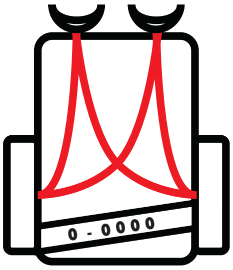
The most dominant genotype for this run was 68, with a structure of [2 1 1 2]



This genotype's internal structure causes both sensors to excite the left motor. This causes the turtle to turn clockwise. Interestingly, in an environment where the goal was to find light, this turtle would spin within a light source and follow it, however, in this environment, being in the lights drains their energy, therefore causing them to slow down, and allow the lights to pass by.

Run 2

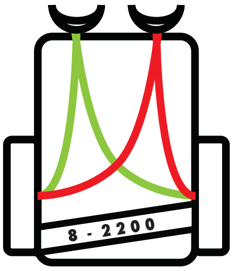
The most dominant genotype for this run was 0, with a structure of [0 0 0 0]



This genotype's internal structure causes both sensors to inhibit both motors, this results in turtles of this genotype moving backwards away from a light source in front of them, however, some turtles of this genotype move backwards, unaware of light behind them, and in to the danger . As a result, this genotype would be better suited to the goal of avoiding light if light approaching from behind caused other sensors to excite the motors, enabling the turtle to escape danger.

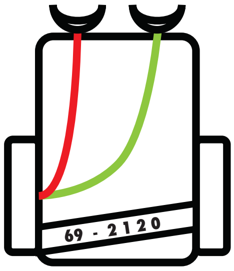
Run 3

The most dominant genotype for this run was 8, with a structure of [0 0 2 2]



This genotype's internal structure causes the left sensor to inhibit both motors, whilst the right sensor excites both motors. A result of this behaviour is that when a light source exists on a turtle of this genotype's right, it will move forward, and when a light source exists on its left, it moves backwards. This behaviour enables the turtles to move out of the way of lights, and then when the light has passed, to remain stationary. One very interesting result of this behaviour was that these turtles would congregate in corners, and when confronted with a light source, would quickly zip through the light, coming out on the other side of the world, and in to a dark zone, thereby allowing their energy to regenerate and enabling reproduction. This demonstrated how turtles of this genotype made use of a flaw in the environment to establish dominance. The screen shot to the right shows this strategy in action.

Run 4



The most dominant genotype for this run was 69, with a structure of [2 1 2 0]

This genotype's internal structure causes the left sensor to excite the left motor, while the right sensor excites the right motor and inhibits the left motor. The resulting behaviour is that when confronted with a light in front of it, a turtle of this genotype will move forwards and to the left quite slowly, however, when a light is on the right, the turtle will turn sharply to the left, and when a light is on the left, the turtle will turn to the right, causing the turtle to spin away from lights. The behaviour of these turtles is not particularly well suited to avoiding a light, which would suggest that they were the dominant genotype purely by lucky of spawning in dark areas, rather than by avoiding lights sufficiently.

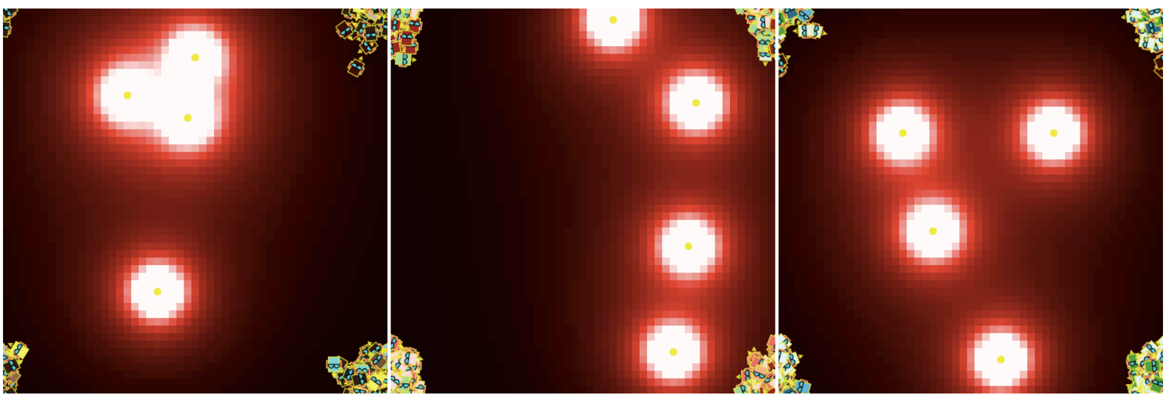
Note

It is interesting to note that whilst this experiment produced some dominant genotypes that were well suited to avoiding / running away from light, it did not produce any dominant genotypes from the previous experiments where the goal was to find light. This is because genotypes that cause turtles to move in to light were quickly weeded out, as they were unsuitable in this new environment, so whilst it is more difficult to find which turtles are particularly good at avoiding light, it is relatively easy to see which ones are not well suited to avoiding light – notable by their absence.

If the simulation allowed the light to wrap around the world, it would be possible that genotypes that were better suited to avoiding light could be the resulting dominant genotypes at the end of the run, however, it is also possible that due to the abundance of dark areas enabling reproduction, the results would be quite similar to those we have already observed. That being said, genotypes such as genotype 8 would not have been able to make use of this flaw in the environment, and therefore would not have established dominance, which demonstrates that what could be perceived as a flaw in the environment, can also be used by certain genotypes to their advantage.

Populations in the Corners

The screen shots below demonstrate the kind of population distribution that was common throughout all worlds after 10,000 ticks. As noted previously, this is as a result of the moving lights rarely coming in to contact with the corners of the world, thus creating a suitable breeding ground for the turtles.



Note, the lights were changed to a red colour in order to create a 'Death Ray' effect which seemed more appropriate when attempting to encourage turtles to avoid a light source.

APPENDIX A

Code

We added the get-zero-or-two procedure.

```
to-report get-zero-or-two
  ifelse(random 10 > 5)
  [report 0]
  [report 2]
end
```

In the mutate-one-codon procedure we modified the following code.

```
to-report mutate-one-codon [current-value]
  let new-value current-value
  if (random-float 100 <= mutation-rate)
   [
     ifelse(force-connections)
     [set new-value get-zero-or-two]
     [set new-value (current-value + random (codon-types - 1) + 1)
      mod codon- types]
   ]
  report new-value
end
```

In the random-gene procedure we modified the following code.

```
to-report random-gene
  ifelse(force-connections)
  [
    report (list (get-zero-or-two)(get-zero-or-two)(get-zero-or-two)
    (get-zero-or-two))
  ]
  [
    report (list (random codon-types) (random codon-types) (random codon-types)
    (random codon-types))
  ]
end
```

We added the user-gene procedure

```
to-report user-gene
  report (list (ls-lm)(ls-rm)(rs-rm)(rs-lm))
end
```

In the setup-vehicle procedure we modified the following code.

```
to setup-vehicle
    ...
    ifelse (user-selected-gene)
            [setup-genotype user-gene]
            [setup-genotype random-gene]
      ...
end
```

In the sense procedure we modified the following code.

```
to sense
  ...
  ifelse (temperature-sensitive and temperature > maxTemperature)
   [set alive false]
   [
     ifelse(death-ray-mode)
     [set energy (energy - temperature)]
     [set energy (energy + temperature)]

     set moving-ave-energy (4 * moving-ave-energy + energy) / 5
   ]
end
```

In the move procedure we modified the following code.

```
to move
    ...
    ifelse(death-ray-mode)
    [set energy energy + 0.02]
    [set energy energy - 0.01]
end
```

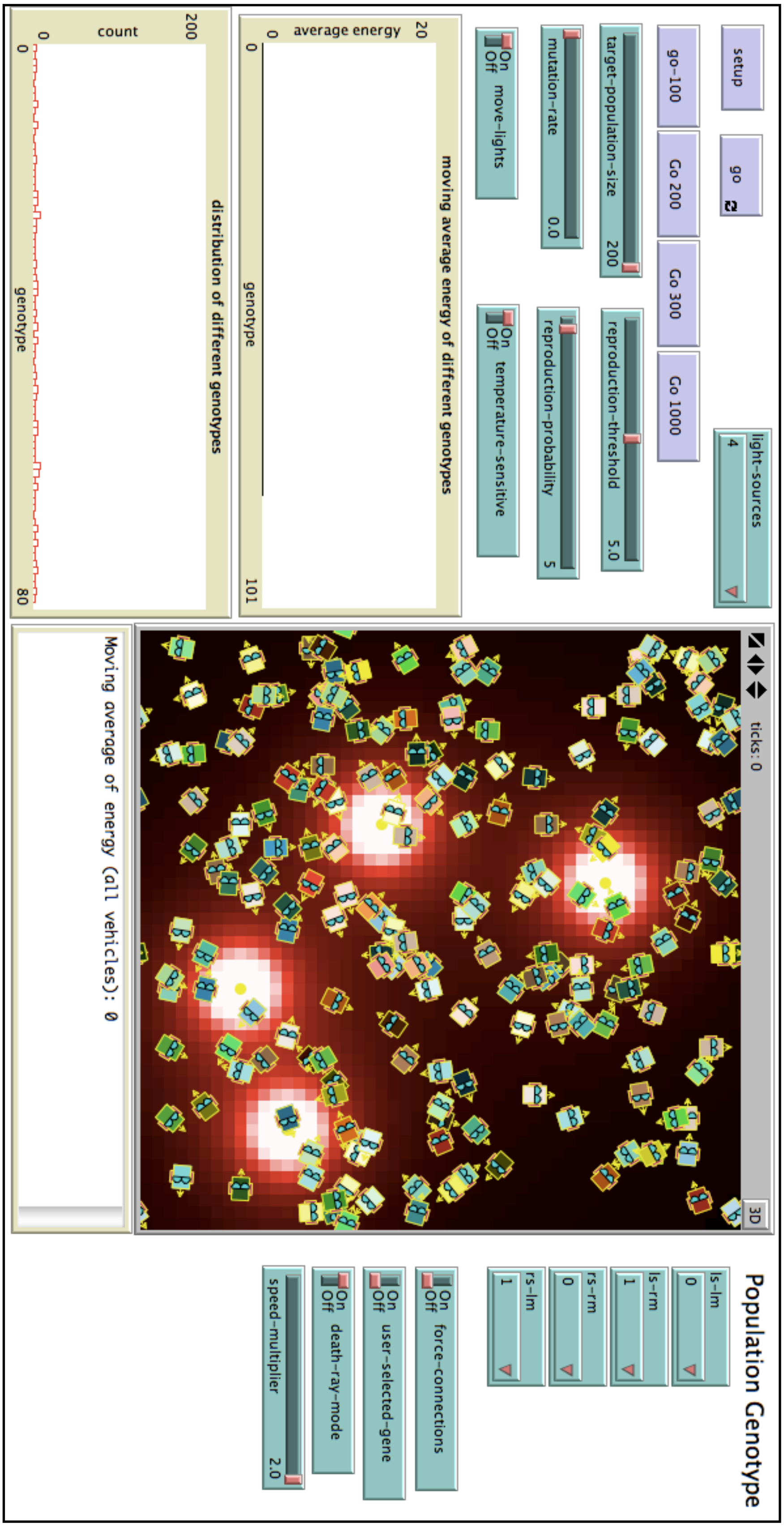
We added the get-death-status procedure.

```
to-report get-death-status
  ifelse(death-ray-mode)
  [report red]
  [report white]
end
```

In the illuminate-patches procedure we modified the following code.

```
to illuminate-patches
  ask patches
  [
    set light-intensity (incident-light pxcor pycor)
    set pcolor scale-color get-death-status (light-intensity / 5) 0 1000
  ]
end
```

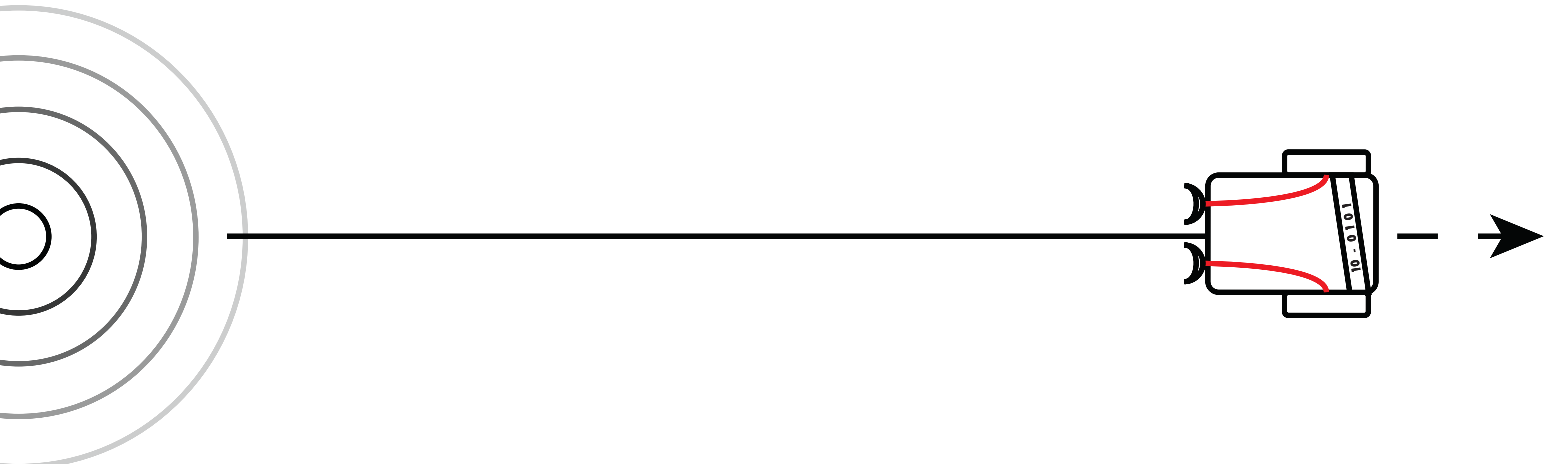
Changes to the User Interface

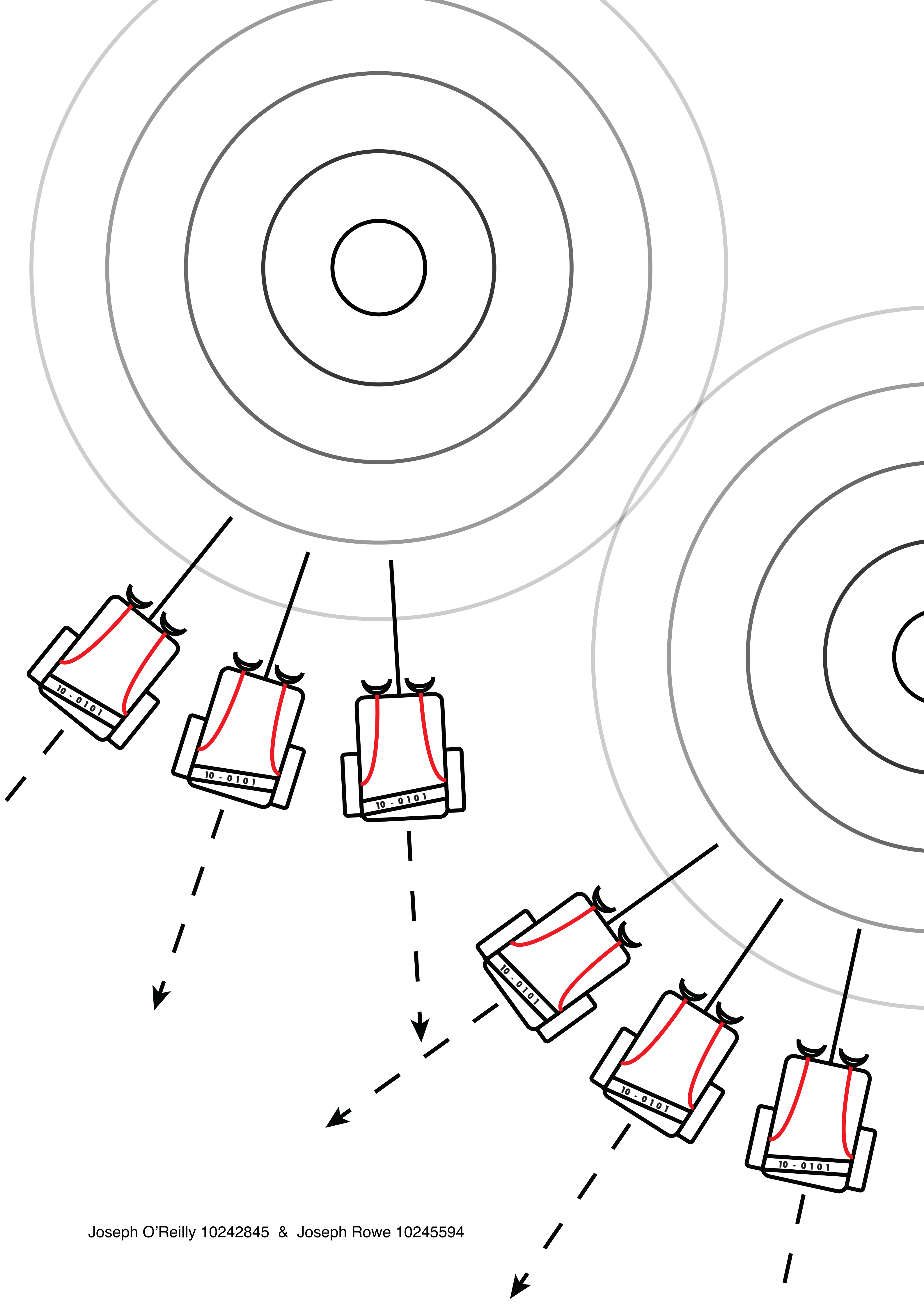


APPENDIX B

Data *(Overleaf)*

During the course of these experiments, we observed the behaviours of various genotypes, and found that despite their simplistic construction, we naturally affixed human personality attributes to them based on their behaviour – for example, genotype 67s tight circles gave off the appearance of tenacity and steadfast determination as it chased the light source across the world, whereas genotype 10s inhibitory connections seemed to indicate a cautious, careful nature, changing to a cool state of relax when it had moved far enough away from the light to stop completely. These are in addition to the usual attributes of “aggressor, lover, scared, etc”, and demonstrate the ease with which we can attribute human attributes to artificial life, and the way it colours or view of the artificial life we are observing.





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