Word Count: 1,894

Introduction

The purpose of this report is to explain the experiments that have been conducted over a constant 50 iterations to see which parameters affect the fitness of the creature generated.
Some of the tools, frameworks and methodologies used were Python, PyBullet and Genetic Algorithms, mainly adapted from the course.
The fitness function was defined through the distance measured from the mountain to the creature, as seen from the image below.

```python
def get_distance_travelled(self):
    if self.start_position is None or self.last_position is None:
        return 0
    current_distance_to_target = np.linalg.norm(self.last_position - self.target_position)
    distance_travelled = self.initial_distance_to_target - current_distance_to_target
    return max(distance_travelled, 0)  # Ensure the distance is always positive
```

Fig 1. Fitness function

Experiment Descriptions

1. Movement Towards Mountain
   The objective of this experiment is to explore the movement capabilities of the creatures towards a simulated mountain environment through adjusting the genetic decoding schemes to optimize the motor controls for moving towards the mountain and climbing it. Where configuration of the PyBullet simulations with a specific starting point and orientations was required.

2. Lower Gene Count of 1, Population Size of 5
   The objective of this experiment is to explore the impact of a reduced genetic count on the creature's fitness through modification of the genetic algorithm's settings to limit the gene count whilst maintaining the population size of 5.

3. Higher Gene Count of 5, Population Size of 5
   The objective of this experiment is to explore the impact of an increased genetic diversity on the creature's fitness through adjustment of the gene count whilst keeping the population size constant.

4. 10 Population Size, Gene Count of 5
   The objective of this experiment is to explore the impact of an increased population size of 10 on the creature's fitness through adjustment of the population size whilst keeping the gene count constant as per the previous experiment.

5. 15 Population Size, Gene Count of 5
   The objective of this experiment is to explore the impact of an increased population size of 15 on the creature's fitness through adjustment of the population size whilst keeping the gene count constant as per the previous experiment.

6. 20 Population Size, Gene Count of 5

The objective of this experiment is to explore the impact of an increased population size of 20 on the creature's fitness through adjustment of the population size whilst keeping the gene count constant as per the previous experiment.

7. 20 Population Size, Link Length of 0.5
   The objective of this experiment is to explore the impact of an increased link length of 0.5 on the creature's fitness through the adjustment of the link length in the genome whilst keeping the previous experiment's parameters constant.

8. 20 Population Size, Link Length of 0.9
   The objective of this experiment is to explore the impact of an increased link length of 0.9 on the creature's fitness through the adjustment of the link length in the genome whilst keeping the previous experiment's parameters constant.

9. 20 Population Size, Link Length of 0.05
   The objective of this experiment is to explore the impact of an decreased link length of 0.9 on the creature's fitness through the adjustment of the link length in the genome whilst keeping the previous experiment's parameters constant.

10. 20 Population Size, Link Length of 0.9, Mass of 0.5
    The objective of this experiment is to explore the impact of an increased link mass of 0.5 on the creature's fitness through the adjustment of the link length in the genome whilst keeping the previous experiment's parameters constant.

11. 20 Population Size, Link Length of 0.9, Mass of 0.01
    The objective of this experiment is to explore the impact of an decreased link mass of 0.01 on the creature's fitness through the adjustment of the link length in the genome whilst keeping the previous experiment's parameters constant.

Results and Observations

1. Movement Towards Mountain
   This was the initial training done without modifying any parameters, treating as a baseline. As seen from the graph below, the fitness of the creature initially had a gradual growth up till the 33th iteration where we will see a huge jump in the fitness score, this could be due to several reasons such as cheating or due to the collisions.

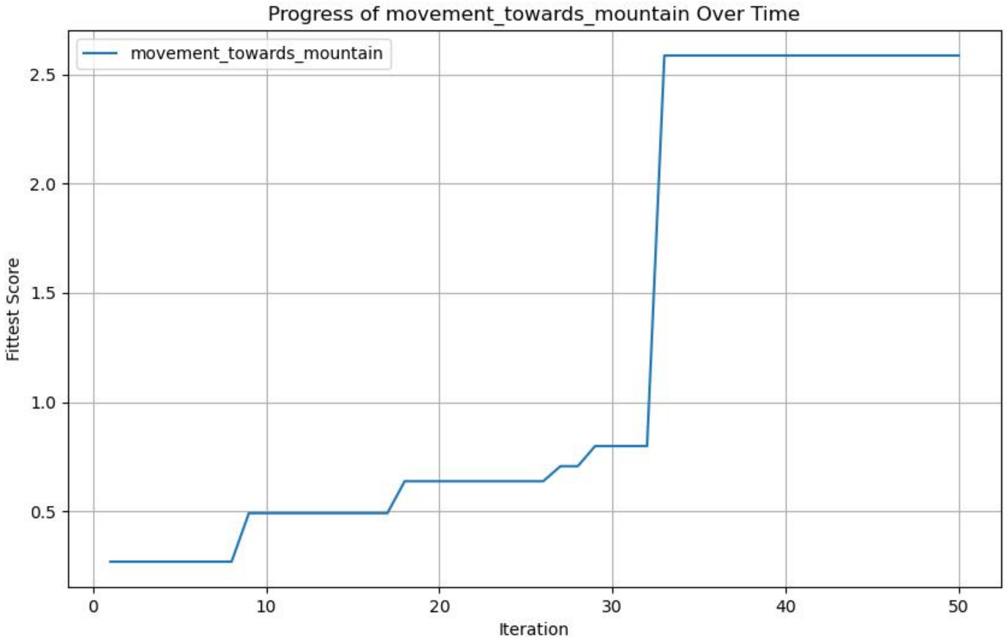


Fig 2. Fitness of Movement Towards Mountain

2. Lower Gene Count of 1, Population Size of 5

   As seen from the graph below, the effects of a lower gene count had a significant impact on the fitness score as the highest score it achieved over 50 iterations was slightly over 0.5.

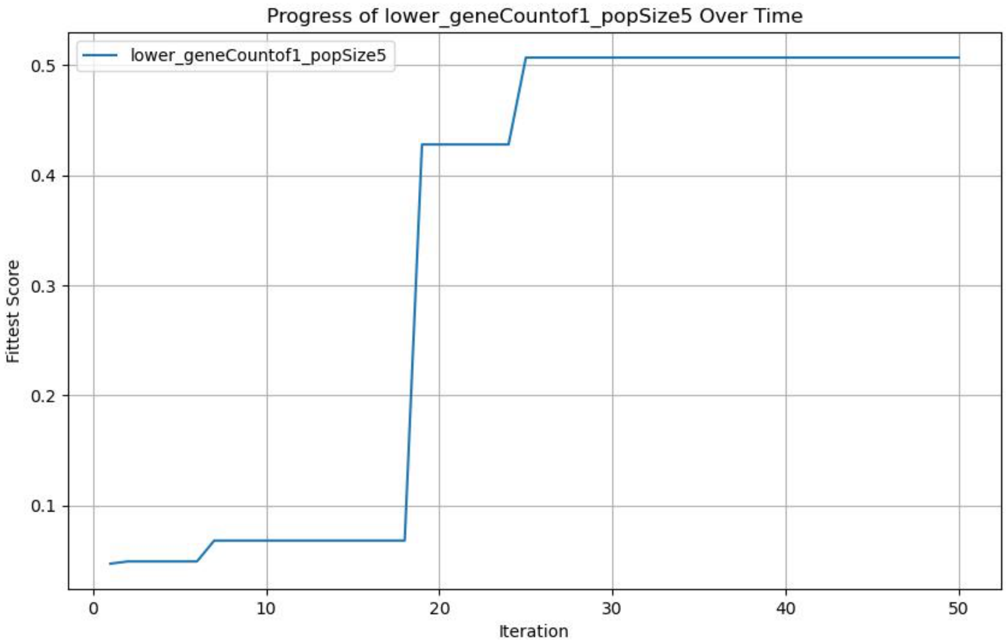


Fig 3. Fitness of Lower Gene Count of 1, Population Size of 5

3. Higher Gene Count of 5, Population Size of 5

As seen from the graph below, the increase in gene count to 5 showed an improvement in fitness score as compared to the lower gene count. This increase of gene count could possibly show that the it would have a direct relationship with the fitness score. Hence, we will keep this gene count for further experiments.

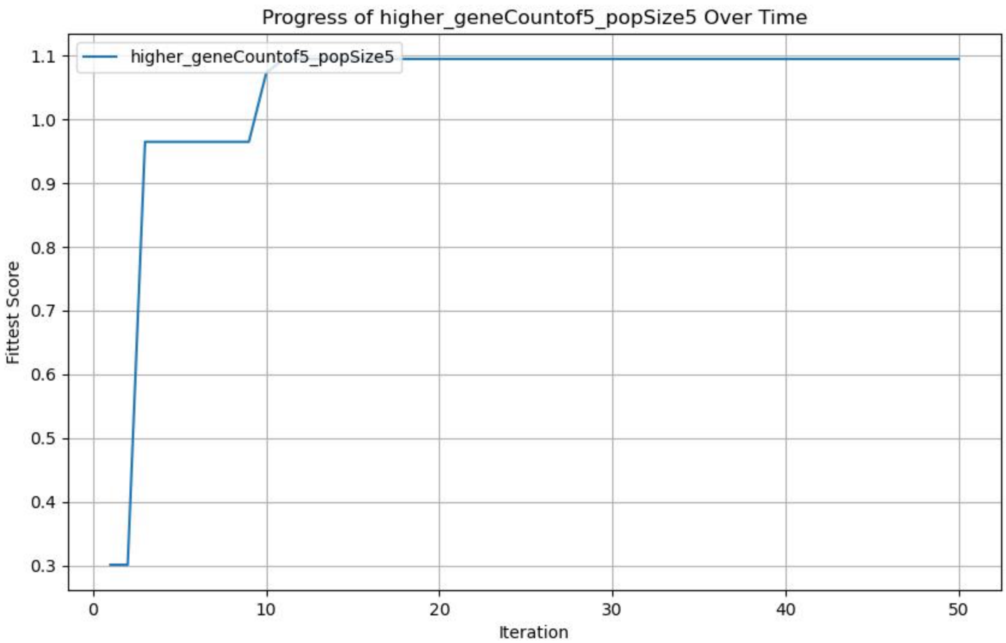


Fig 4. Fitness of Higher Gene Count of 5, Population Size of 5

4. 10 Population Size, Gene Count of 5
   For this experiment, we will be focusing on increasing the population size to 10 and as seen from the graph below, the fitness score's increase was slightly more gradual as compared to the previous experiment and it also had a sharp increase in the initial iterations. It also achieved a similar fitness score of 1.1.

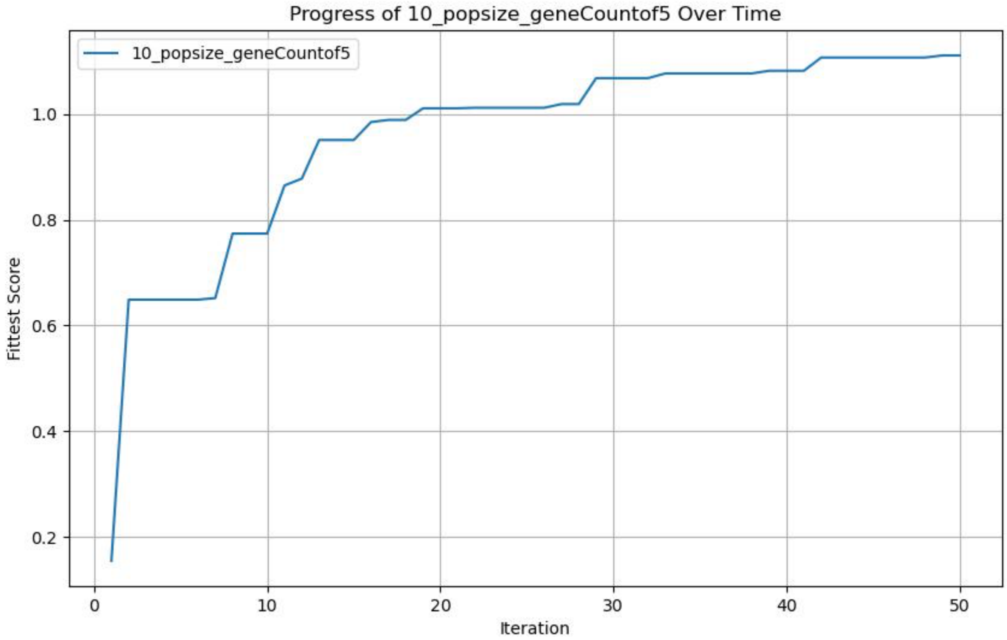


Fig 5. Fitness of 10 Population Size, Gene Count of 5

5. 20 Population Size, Gene Count of 5
   Next, we will try to increase the population size to 20 to see if there's any difference in the gradient of the graph or if there's a higher fitness score. As seen from the graph, the gradient of the graph is similar to the previous experiment, where there is a sharp increase in fitness scores in the first 10 iterations. In addition, there is also a higher fitness score of slightly above 1.2. Since this has been the highest fitness score for the population size experimentation, we will keep the population size of 20 for the next experiments.

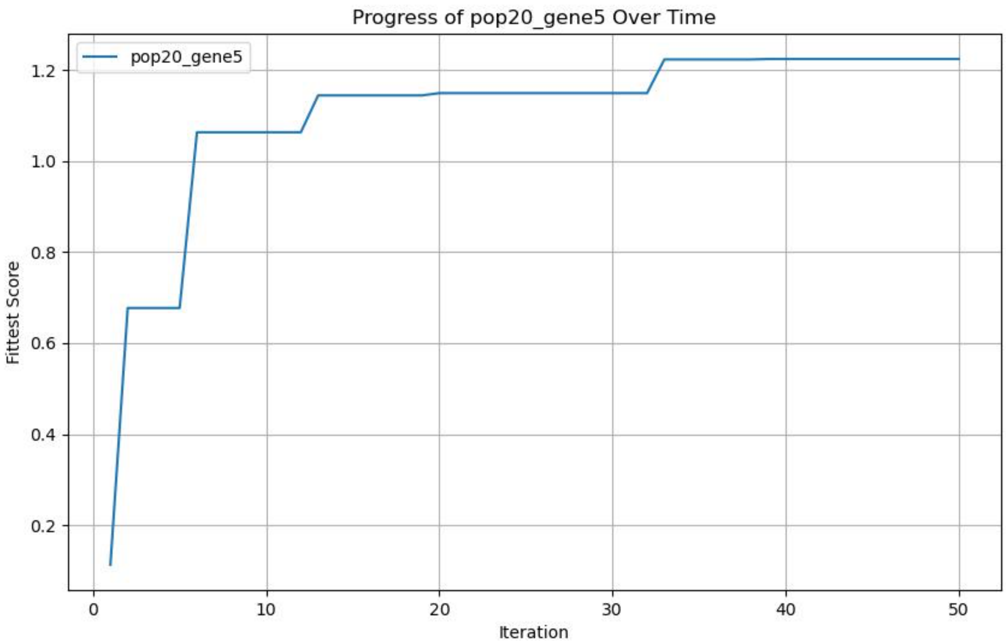


Fig 6. Fitness of 20 Population Size, Gene Count of 5

6. 20 Population Size, Link Length of 0.5
   The next parameter that we will be experimenting on will be the link-length, where we increased it to 0.5. As seen from the graph directly below, there is a sharp increase in the fitness score within the first 5 iterations and it only had a slight increase over the next 45 iterations.

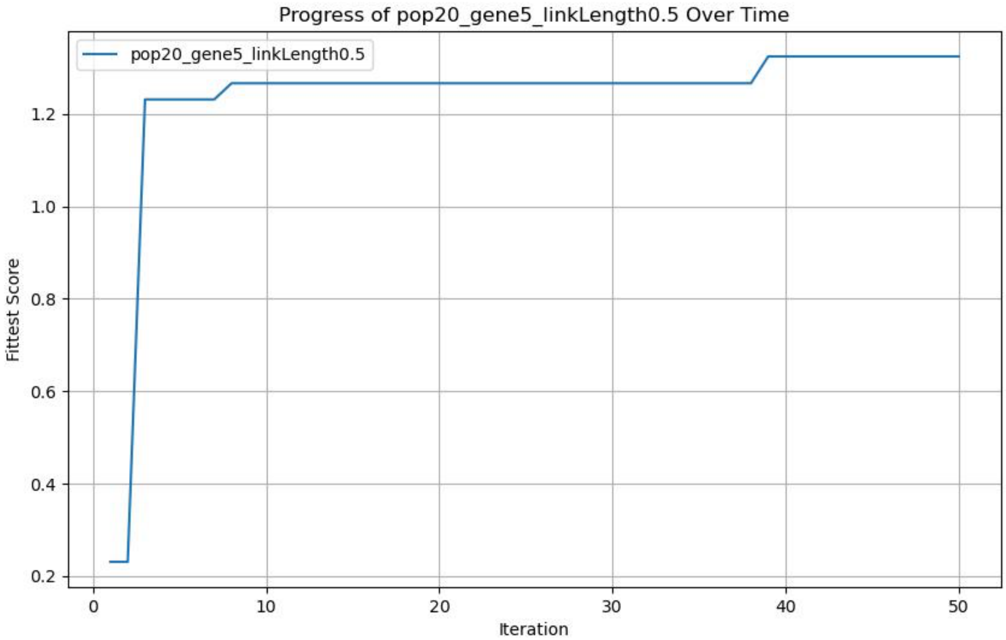


Fig 7.1. Fitness of 20 Population Size, Link Length of 0.5

As we can see, from Figure 7.2, there is a clear mutation in the 2nd iteration whereby the total link length increased sharply as compared to the 1st iteration which could be the explanation for the sharp increase shown in Figure 7.1.

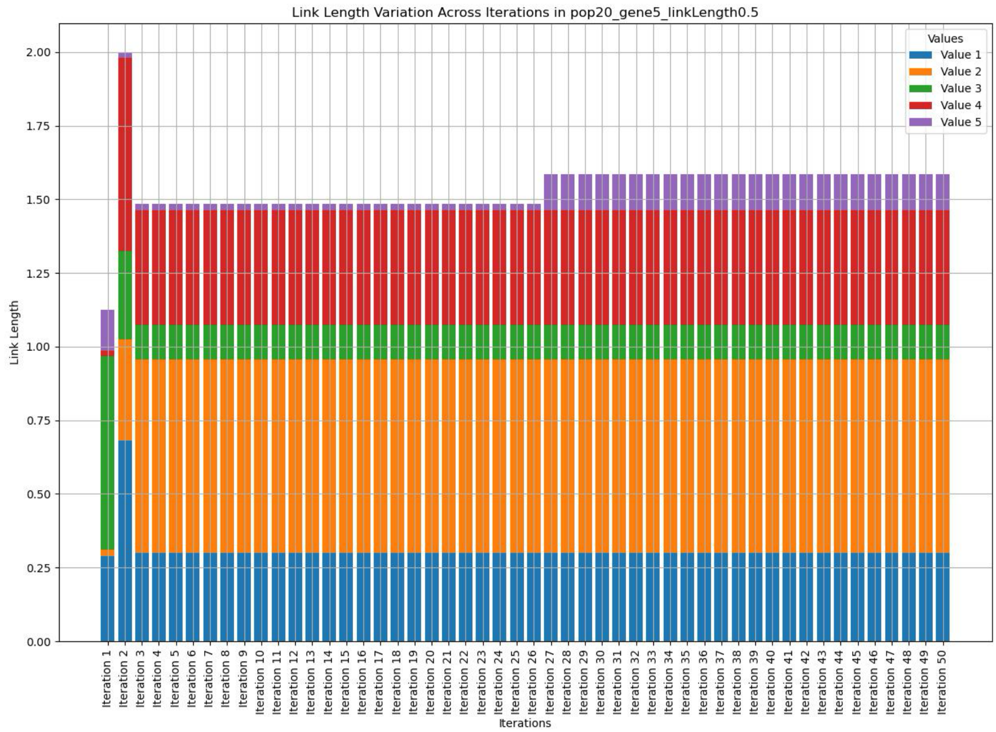


Fig 7.2. Link Length of 20 Population Size, Link Length of 0.5

7. 20 Population Size, Link Length of 0.9
   Next we will try to increase the link-length to 0.9 where it achieved a higher overall fitness score of slightly more than 1.4 and the fitness score graph is slightly more gradual than the previous experiment.

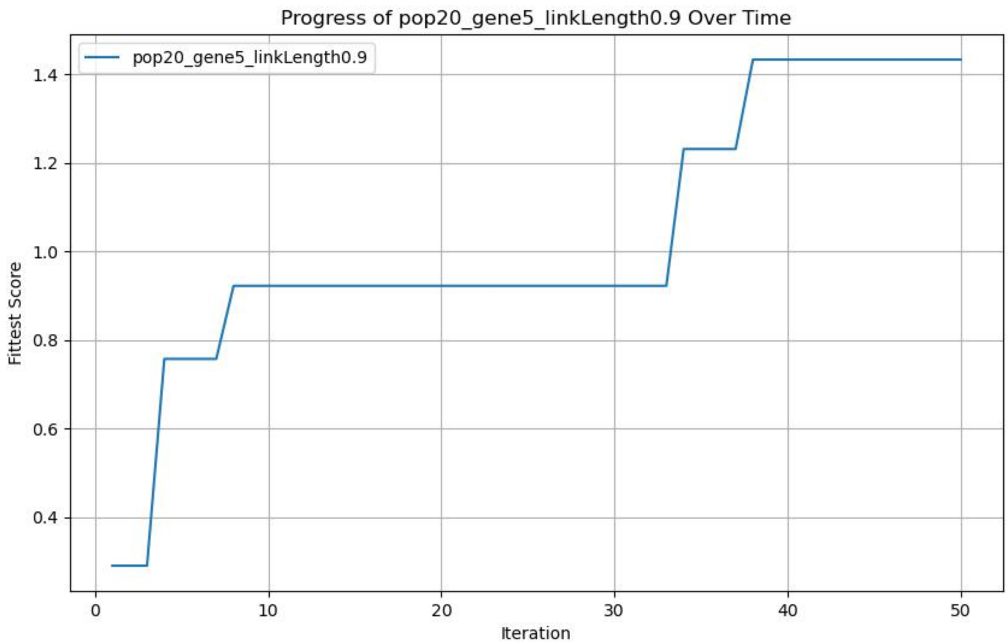
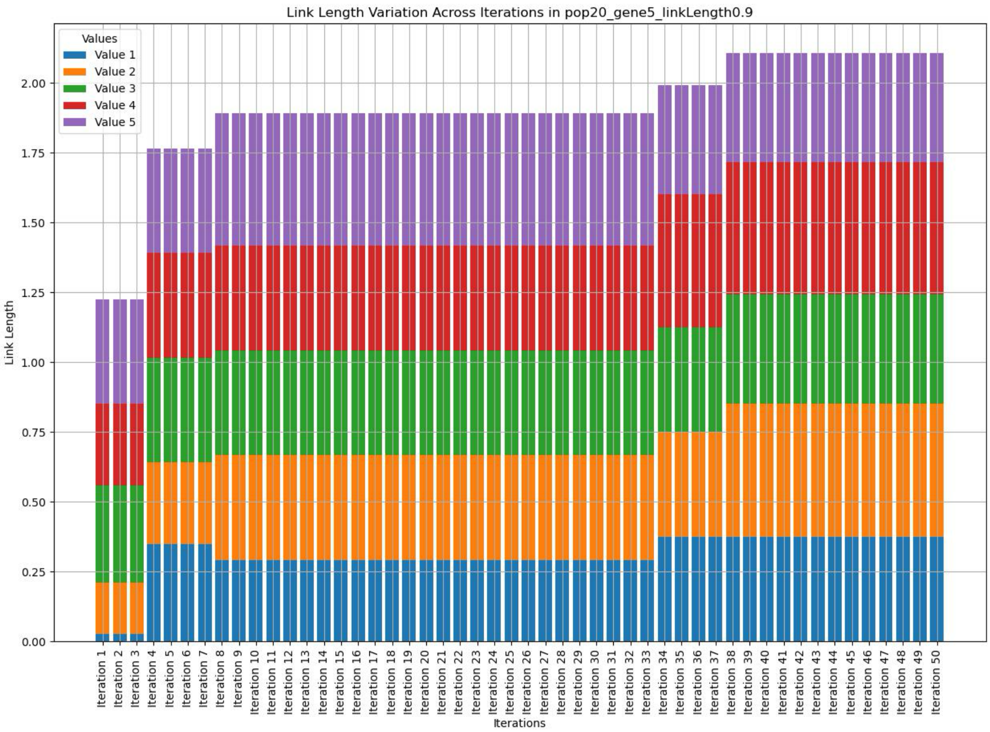


Fig 8.1. Fitness of 20 Population Size, Link Length of 0.9

As seem from Figure 8.2, the number of links and overall length also increased over the number of iterations which tells us that the link length and fitness score has a direct relationship.



<u>Fig 8.2. Link Length of 20 Population Size, Link Length of 0.9</u>

8. 20 Population Size, Link Length of 0.05

   Next we will try to experiment a smaller link length of 0.05 to prove our theory, this produced a end fitness score of slightly above 1.1 which is lesser than our previous experiment. Hence, we will keep the link length of 9 for our next experiments.

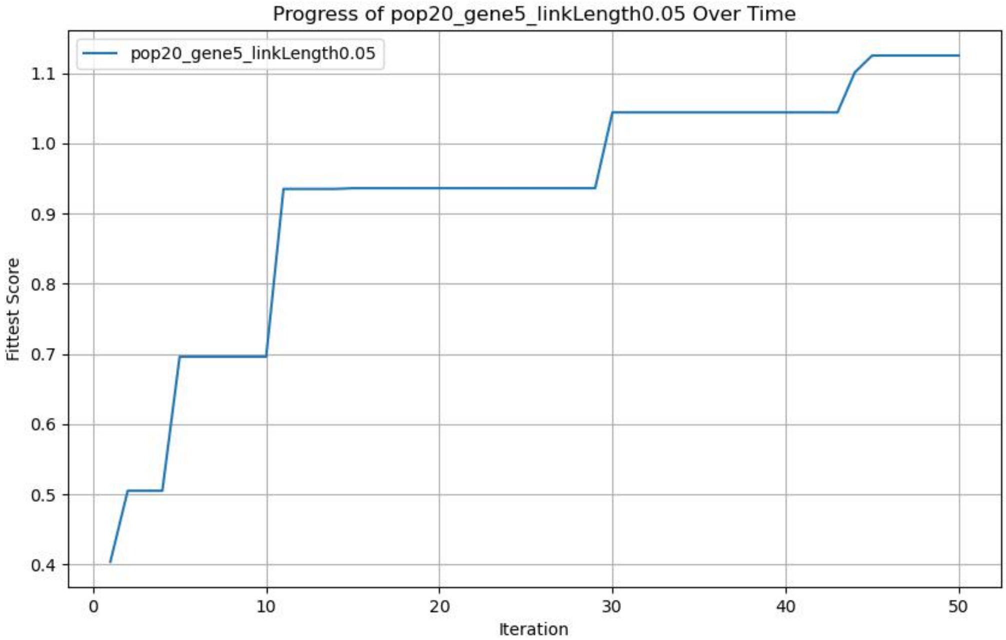


Fig 9.1. Fitness of 20 Population Size, Link Length of 0.05

A reduction in the link length parameter showed a decrease in the general link length as seen from Figure 9.2.

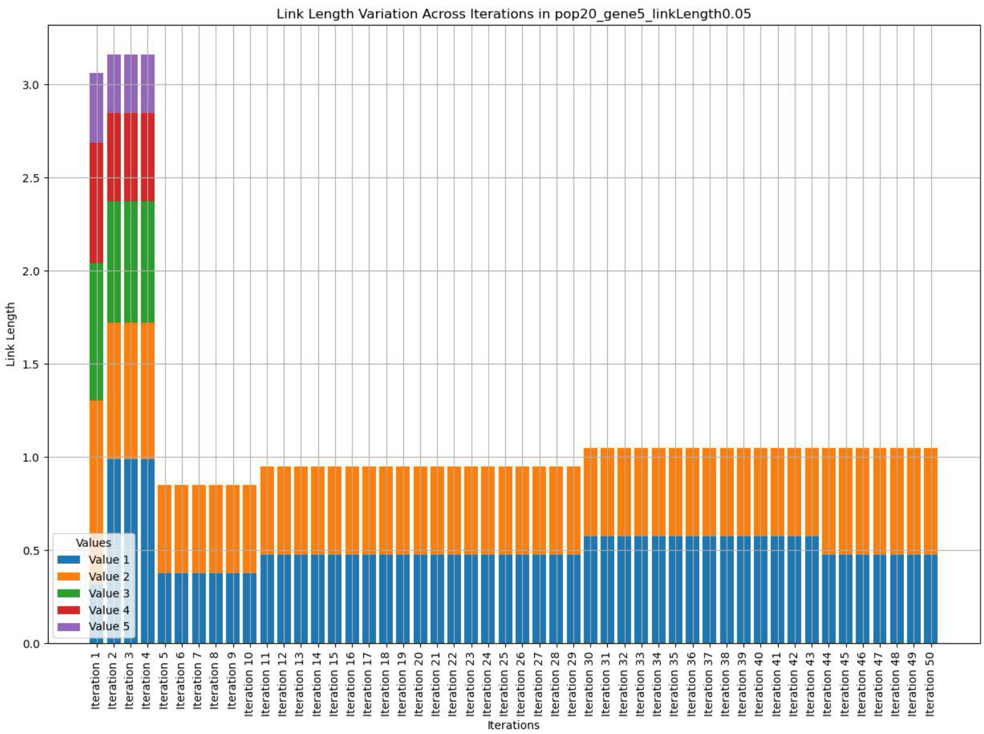


Fig 9.2. Link Length of 20 Population Size, Link Length of 0.05

9. 20 Population Size, Link Length of 0.9, Mass of 0.5

Next, we will experiment with the link-mass where we tried to increase the link mass to 0.5. As seen from Figure 10.1, the increase in link mass generated a fitness score around 1.25 and the graph is more gradual in its increase.

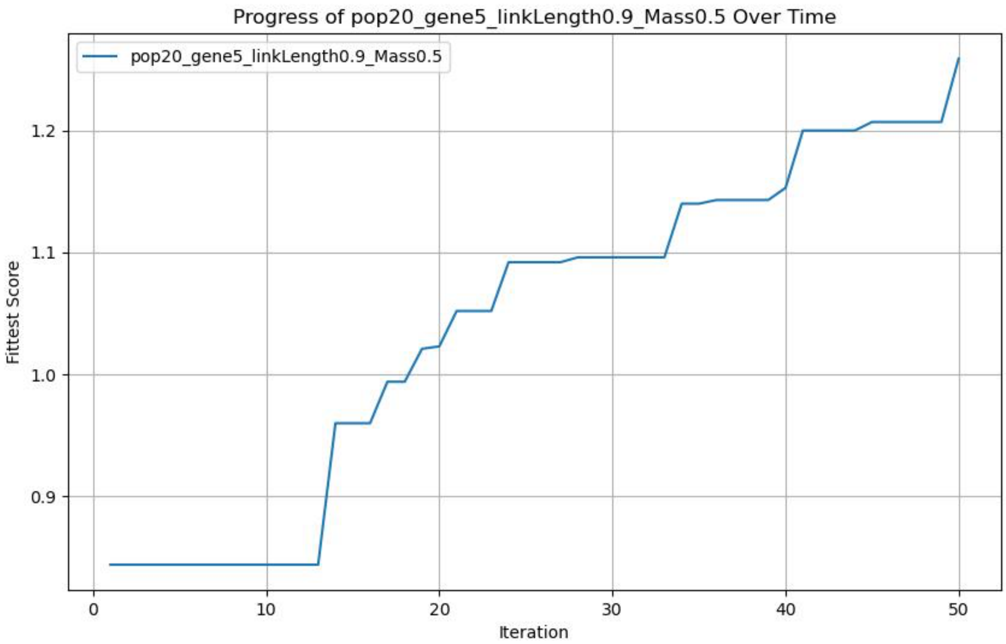


Fig 10.1. Fitness of 20 Population Size, Link Length of 0.9, Mass of 0.5

As seen from Figure 10.2, the increase in link mass resulted in the link mass increasing as well as the number of links.

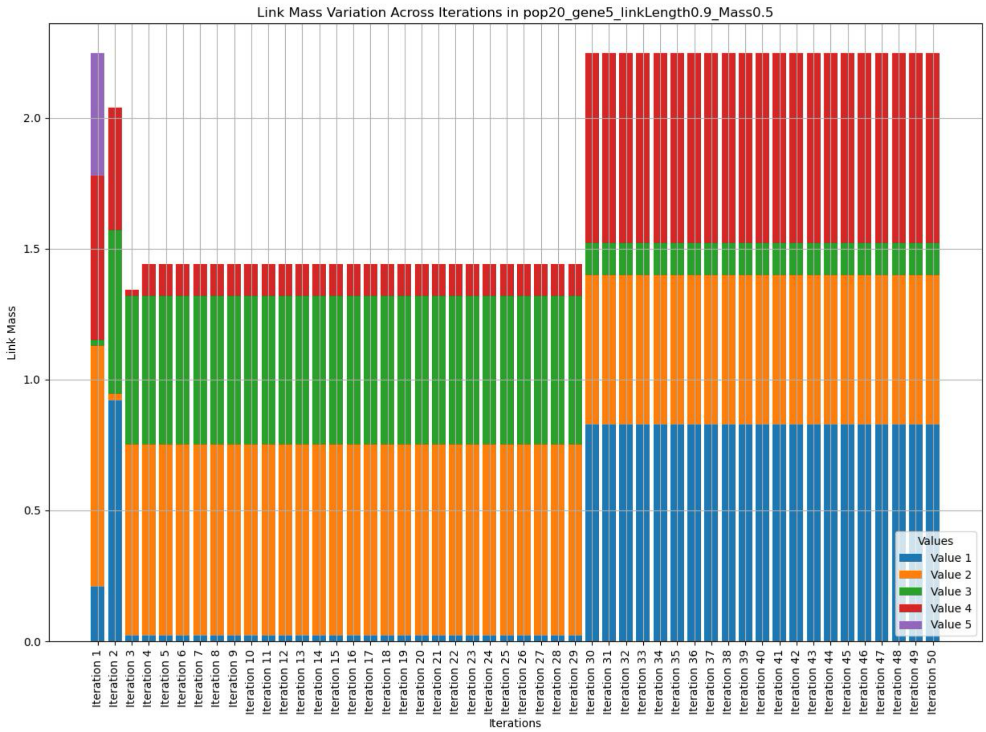
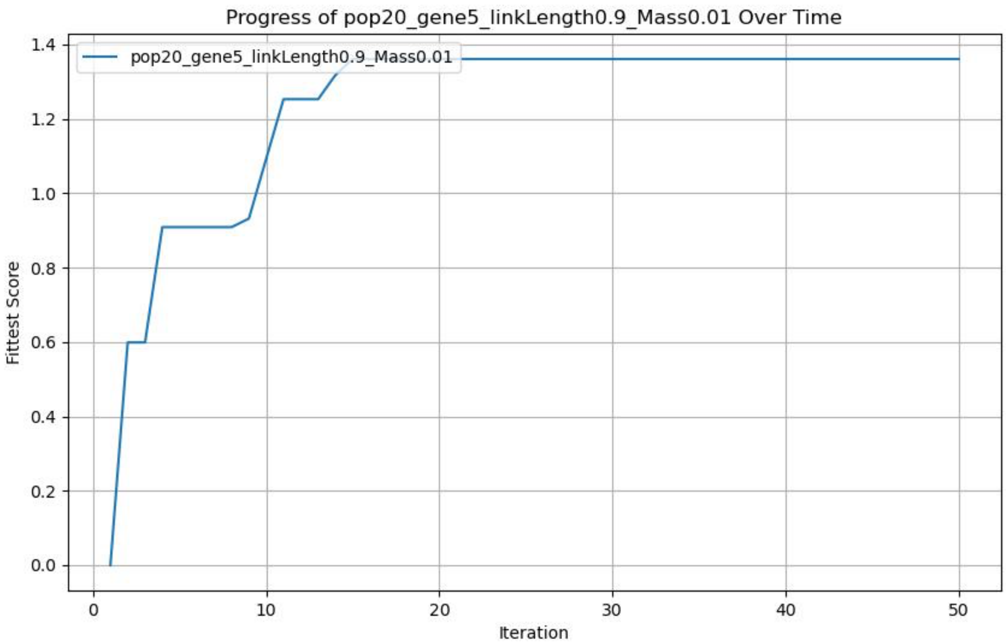


Fig 10.2. Link Mass of 20 Population Size, Link Length of 0.9, Mass of 0.5

10. 20 Population Size, Link Length of 0.9, Mass of 0.01
    Next, we will experiment with a lower link mass of 0.01 where it produced a fitness score of almost 1.4, which is an improvement as compared to the previous experiment. Hence, we will use this parameter score.



<u>Fig 11.1. Fitness of 20 Population Size, Link Length of 0.9, Mass of 0.01</u>

As seen from Figure 11.2, the reduction in link mass resulted in a lower link mass produced and the number of links also reduced.

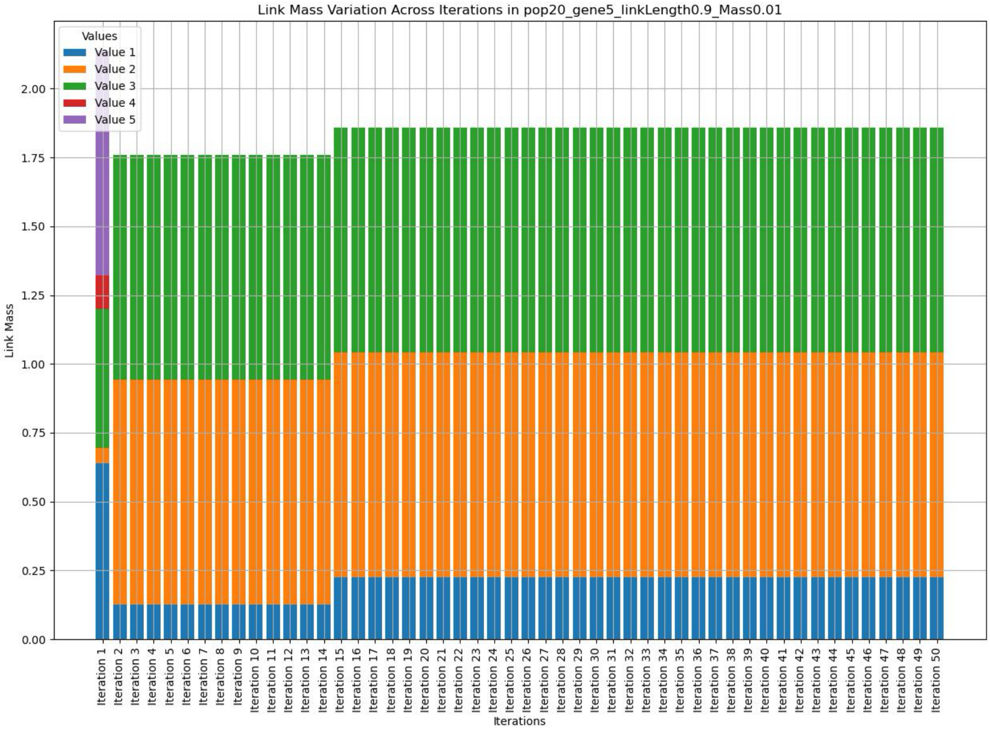


Fig 11.2. Link Mass of 20 Population Size, Link Length of 0.9, Mass of 0.01

Analysis and Discussions

Overall, the best parameters that produced the best results during the experiments is:

- Gene Count: 5
- Population Size: 20
- Link Length: 0.9
- Link Mass: 0.01

This means that an increase in gene count, population size, and link length and a decrease in link mass resulted in the best performing experiment.

Experiment	Fittest Fitness Score
Movement Towards Mountain	2.586
Lower Gene Count of 1, Population Size 5	0.507
Higher Gene Count of 5, Population Size 5	1.095
10 Population Size, Gene Count of 5	1.107
20 Population Size, Gene Count of 5	1.224
20 Population Size, Link Length of 0.5	1.324
20 Population Size, Link Length of 0.9	1.434
20 Population Size, Link Length of 0.05	1.125
20 Population Size, Link Length 0.9, Mass of 0.5	1.207
20 Population Size, Link Length 0.9, Mass of 0.01	1.361

As seen from the table above, the increase in fitness scores with higher gene count and larger populations can be explained where greater diversity leads to a better exploration of the solution space. Similarly, longer link lengths and lighter link masses likely contributed to better manoeuvrability and efficiency in movement

Limitations

The results of the graph was only for 50 iterations so the training of the creature was not as exhaustive. This was due to several factors such as threaded limitations as the experiments was conducted on an M1 MacBook.

Another limitation would be that the results are specific to the simulated mountain environment and the particular genetic algorithm may not generalize to other types of environments or creatures.

Conclusion

In conclusion, the experiments conducted identified the optimal parameters for improving the fitness of creatures in a simulated environment. The findings above suggest that increasing gene count, population size, along with the optimization of physical attributes of the creature can enhance the performance.

We could possibly explore these in the future:

- Longer iterations to fully exploit the potential of the genetic algorithm
- Different environments
- Altering genetic parameters such as crossover and mutation to further enhance the performance.

By addressing these areas, we can gain a deeper understanding of the evolutionary dynamics and improve the design of the creatures in simulated environments.