

# Assignment 1 Report

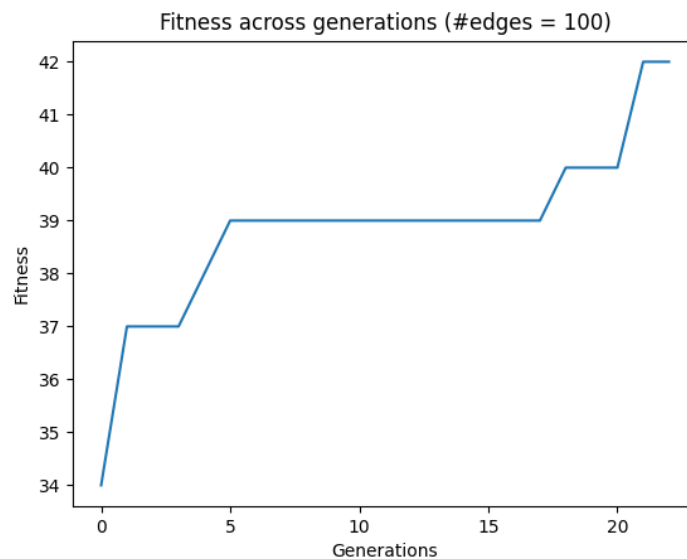
The Genetic algorithm for the Vertex Coloring problem with three colors for a graph with 50 vertices is implemented.

## 1. Basic Genetic Algorithm

The following plots show the performance of the basic Genetic algorithm (Textbook version) for a different number of edges. All the plots are implemented with a default configuration of population size = 100 and generation limit = 50:

- Edges = 100

```
Roll no: 2021H1030029G
Number of edges: 100
Best state:
0:R, 1:B, 2:B, 3:G, 4:R, 5:R, 6:G, 7:G, 8:G, 9:B, 10:G, 11:G, 12:G, 13:B, 14:B, 15:R, 16:B, 17:B, 18:R, 19:G, 20:R, 21:G, 22:G, 23:R, 24:B, 25:R, 26:G, 27:B, 28:B, 29:G, 30:R, 31:R, 32:B, 33:B, 34:B, 35:B, 36:B, 37:R, 38:G, 39:R, 40:R, 41:B, 42:B, 43:G, 44:B, 45:R, 46:G, 47:B, 48:G, 49:B
Fitness value of best state: 42
Time taken: 45.24 seconds
```



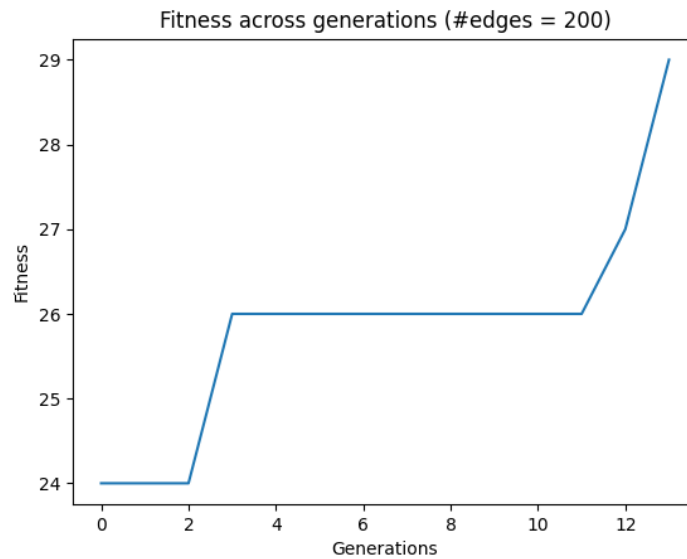
The best fitness value of 42 was obtained for a random graph of 100 edges with approximately 22 generations.

- Edges = 200

```

Roll no: 2021H1030029G
Number of edges: 200
Best state:
0:R, 1:B, 2:B, 3:G, 4:R, 5:R, 6:G, 7:B, 8:R, 9:B, 10:B, 11:G, 12:B, 13:B, 14:R, 15:B, 16:G, 17:G, 18:G, 19:B, 20:R, 21:R, 22:G, 23:B, 24:R, 25:G, 26:R, 27:G, 28:B, 29:R, 30:R, 31:B, 32:B, 33:G, 34:B, 35:G, 36:G, 37:G, 38:G, 39:B, 40:R, 41:G, 42:B, 43:B, 44:B, 45:B, 46:R, 47:G, 48:G, 49:R
Fitness value of best state: 29
Time taken: 47.69 seconds

```



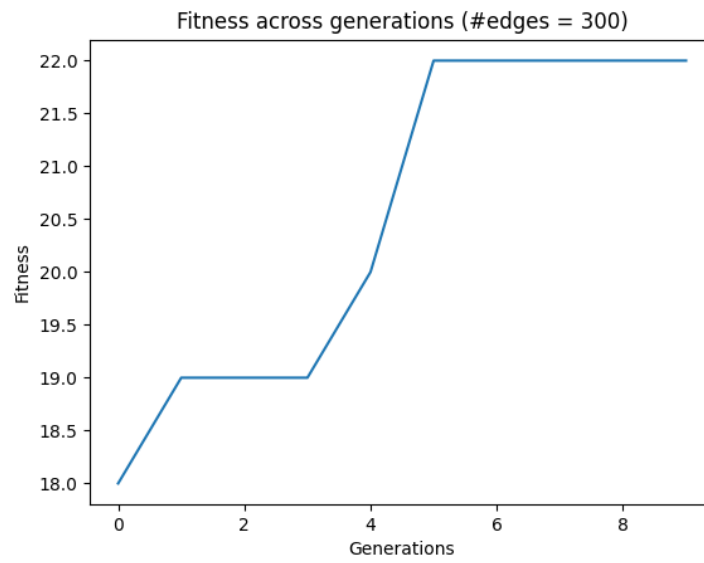
The best fitness value of 29 was obtained for a random graph of 200 edges with approximately 13 generations.

- Edges = 300

```

Roll no: 2021H1030029G
Number of edges: 300
Best state:
0:R, 1:G, 2:B, 3:R, 4:G, 5:G, 6:R, 7:G, 8:R, 9:R, 10:B, 11:B, 12:B, 13:R, 14:B, 15:R, 16:G, 17:G, 18:G, 19:B, 20:R, 21:R, 22:R, 23:B, 24:B, 25:R, 26:R, 27:R, 28:B, 29:G, 30:G, 31:G, 32:G, 33:R, 34:B, 35:G, 36:B, 37:G, 38:R, 39:B, 40:R, 41:G, 42:R, 43:R, 44:G, 45:B, 46:G, 47:G, 48:G, 49:G
Fitness value of best state: 22
Time taken: 48.41 seconds

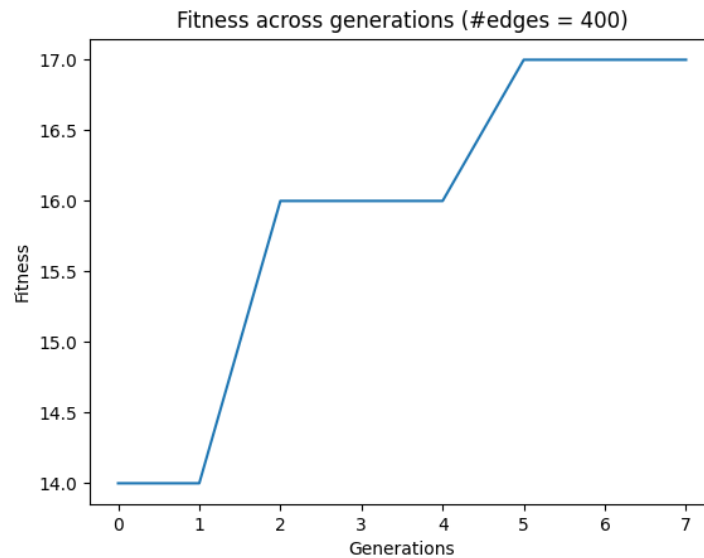
```



The best fitness value of 22 was obtained for a random graph of 300 edges with approximately 9 generations.

- Edges = 400

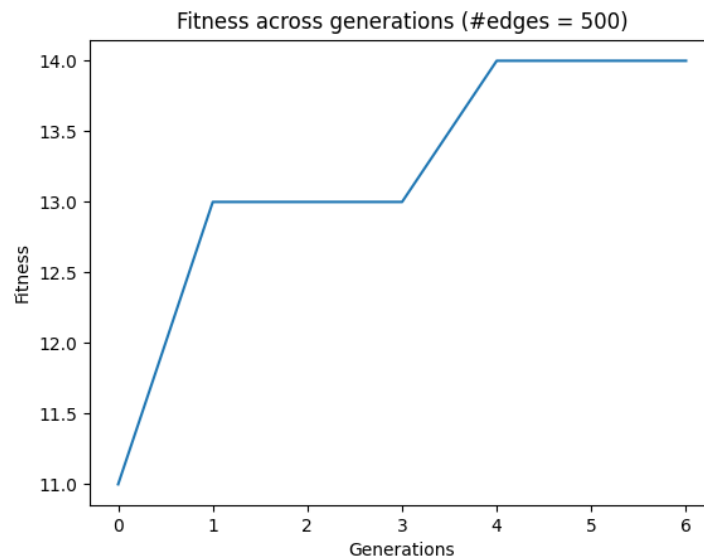
```
Roll no: 2021H1030029G
Number of edges: 400
Best state:
0:G, 1:R, 2:R, 3:G, 4:B, 5:G, 6:B, 7:B, 8:G, 9:B, 10:R, 11:B, 12:G, 13:G, 14:G, 15:R, 16:B, 17:R, 18:R, 19:R, 20:R, 21:B, 22:
:B, 23:R, 24:B, 25:R, 26:B, 27:B, 28:B, 29:G, 30:R, 31:G, 32:B, 33:R, 34:R, 35:B, 36:B, 37:B, 38:R, 39:G, 40:R, 41:B, 42:R,
43:G, 44:B, 45:G, 46:G, 47:G, 48:B, 49:B
Fitness value of best state: 17
Time taken: 48.8 seconds
```



The best fitness value of 17 was obtained for a random graph of 400 edges with approximately 7 generations.

- Edges = 500

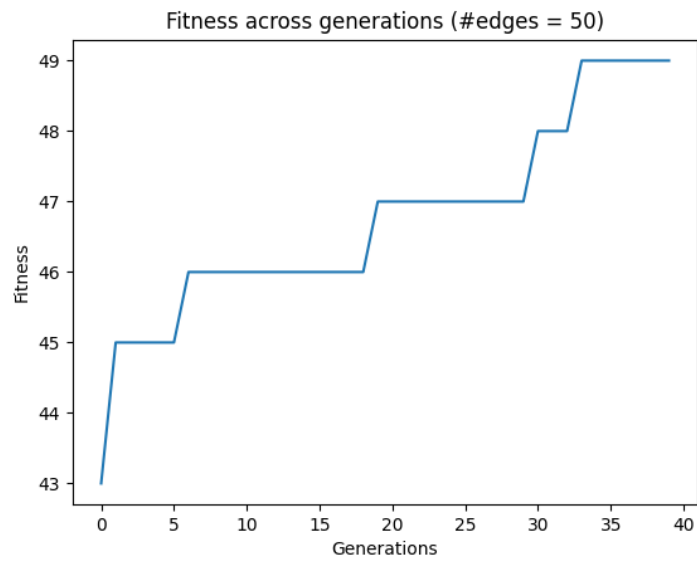
```
Roll no: 2021H1030029G
Number of edges: 500
Best state:
0:R, 1:G, 2:R, 3:R, 4:G, 5:G, 6:G, 7:B, 8:B, 9:B, 10:G, 11:B, 12:R, 13:G, 14:G, 15:R, 16:R, 17:R, 18:G, 19:B, 20:G, 21:R, 22:R, 23:B, 24:G, 25:G, 26:R, 27:B, 28:B, 29:B, 30:B, 31:G, 32:B, 33:R, 34:G, 35:G, 36:B, 37:G, 38:R, 39:B, 40:G, 41:R, 42:B, 43:R, 44:B, 45:B, 46:B, 47:G, 48:G, 49:B
Fitness value of best state: 14
Time taken: 48.68 seconds
```



The best fitness value of 14 was obtained for a random graph of 500 edges with approximately 6 generations.

- Testcase edges = 50

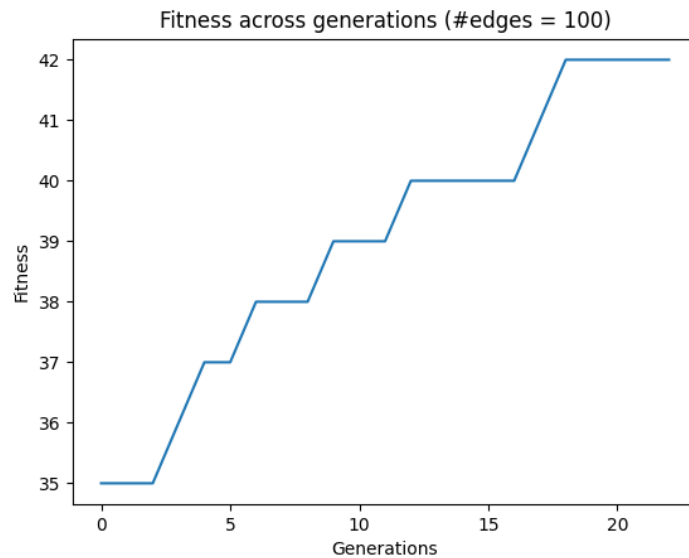
```
Roll no: 2021H1030029G
Number of edges: 50
Best state:
0:G, 1:B, 2:G, 3:R, 4:R, 5:G, 6:B, 7:G, 8:R, 9:R, 10:R, 11:B, 12:G, 13:R, 14:G, 15:R, 16:G, 17:G, 18:R, 19:R, 20:B, 21:B, 22:B, 23:G, 24:R, 25:G, 26:G, 27:R, 28:B, 29:B, 30:B, 31:R, 32:R, 33:R, 34:G, 35:G, 36:G, 37:G, 38:B, 39:G, 40:R, 41:R, 42:B, 43:B, 44:R, 45:R, 46:B, 47:B, 48:G, 49:R
Fitness value of best state: 49
Time taken: 45.28 seconds
```



The best fitness value of 49 was obtained for a testcase graph of 50 edges with approximately 40 generations.

- Testcase edges = 100

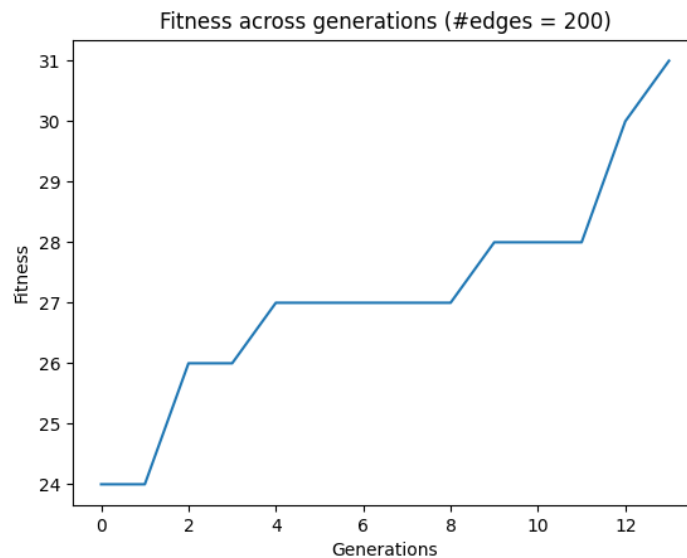
```
Roll no: 2021H1030029G
Number of edges: 100
Best state:
0:B, 1:G, 2:R, 3:B, 4:G, 5:B, 6:G, 7:G, 8:B, 9:B, 10:G, 11:B, 12:R, 13:G, 14:B, 15:G, 16:B, 17:G, 18:R, 19:G, 20:G, 21:R, 22:
:B, 23:G, 24:B, 25:R, 26:R, 27:B, 28:R, 29:B, 30:R, 31:B, 32:G, 33:R, 34:G, 35:R, 36:R, 37:G, 38:B, 39:R, 40:R, 41:B, 42:B,
43:B, 44:R, 45:B, 46:R, 47:G, 48:G, 49:G
Fitness value of best state: 42
Time taken: 46.01 seconds
```



The best fitness value of 42 was obtained for a testcase graph of 100 edges with approximately 22 generations.

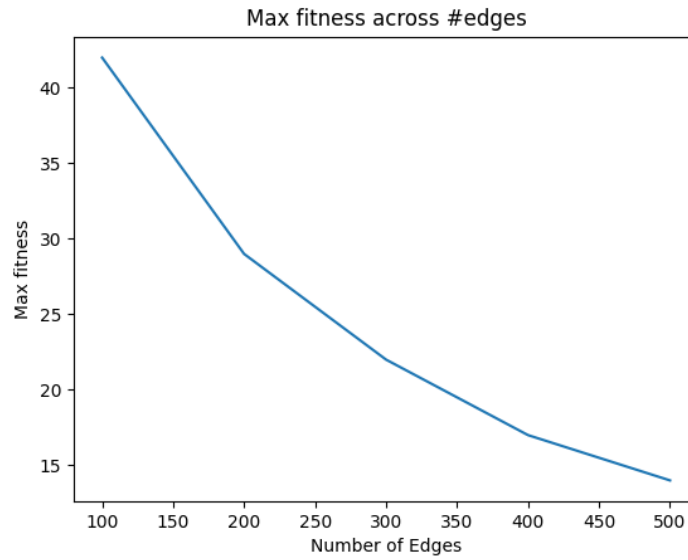
- Testcase edges = 200

```
Roll no: 2021H1030029G
Number of edges: 200
Best state:
0:R, 1:R, 2:G, 3:B, 4:R, 5:G, 6:G, 7:R, 8:B, 9:G, 10:G, 11:G, 12:G, 13:R, 14:B, 15:G, 16:R, 17:R, 18:G, 19:B, 20:B, 21:R, 22
:B, 23:G, 24:B, 25:R, 26:B, 27:R, 28:G, 29:B, 30:R, 31:G, 32:G, 33:B, 34:B, 35:G, 36:B, 37:B, 38:B, 39:R, 40:G, 41:B, 42:G,
43:B, 44:R, 45:B, 46:R, 47:G, 48:G, 49:R
Fitness value of best state: 31
Time taken: 46.97 seconds
```

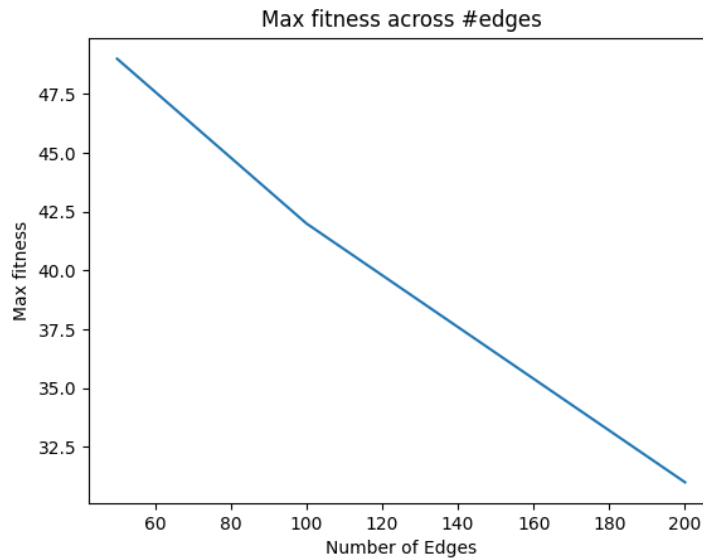


The best fitness value of 31 was obtained for a testcase graph of 200 edges with approximately 13 generations.

The above results are obtained after executing the Genetic algorithm atleast 10 times for each case and the best results are shown. Following plot shows the maximum fitness value obtained for random graphs with edges - 100, 200, 300, 400, 500 and testcase graphs with edges - 50, 100, 200.



(a) Max fitness for random graphs with different number of edges



(b) Max fitness for testcase graphs with different number of edges

## 2. Improved Genetic Algorithm

The basic Genetic algorithm is improved with certain changes to the configuration/parameters such as population size and generation limit. Following are the various improvements made to the algorithm:

- Generating 2 children instead of one

At each iteration where a new child is generated using

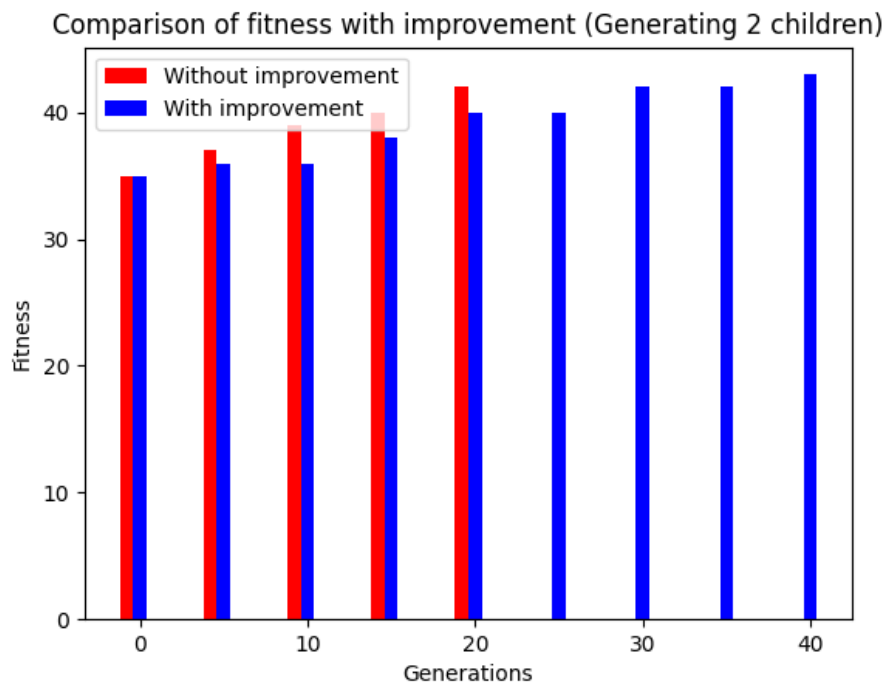
```
child = parent1[:split_point] + parent2[:split_point],
```

the algorithm is improved by generating 2 children instead of one using same parents as shown below:

```
child1 = parent1[:split_point] + parent2[split_point:]
```

```
child2 = parent2[:split_point] + parent1[split_point:]
```

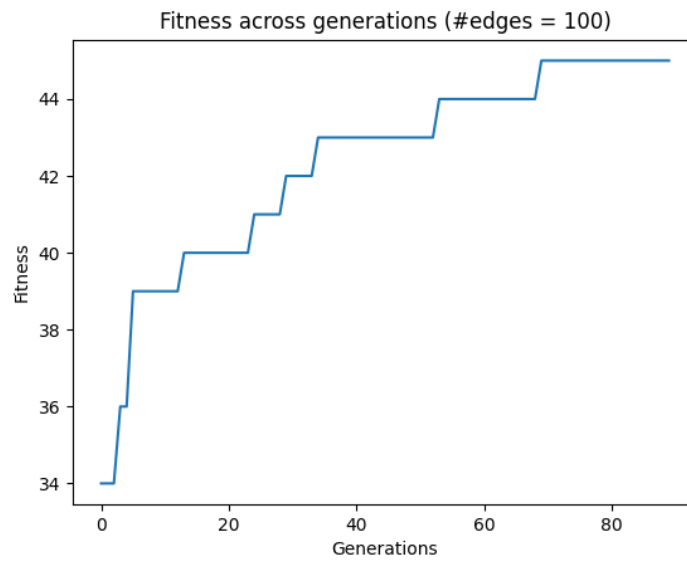
This helps in reducing the overall time taken by the algorithm to generate new population and hence the algorithm is able to reach new limits of generations within the 45 seconds time frame as well as better fitness (in some cases) as shown below:



- Population size = 50 & Generation limit = 100

Following plot shows the readings for testcase graph with 100 edges with population size = 50 and generation limit = 100.

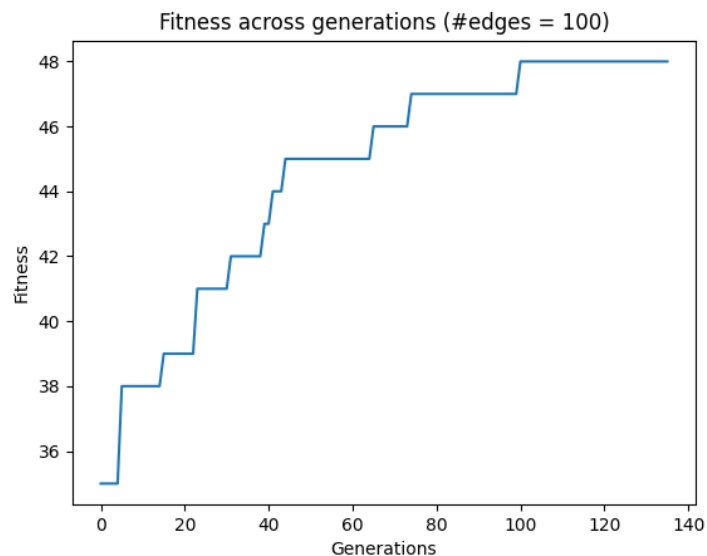




Basic Algorithm	Improved Algorithm
Number of edges = 100 Fitness value of best state = 42 Time taken ~ 46 seconds Number of generations ~ 22	Number of edges = 100 Fitness value of best state = 45 Time taken ~ 20 seconds Number of generations ~ 85

- Population size = 20 & Generation limit = 150

Following plot shows the readings for testcase graph with 100 edges with population size = 20 and generation limit = 150.



Basic Algorithm	Improved Algorithm
Number of edges = 100 Fitness value of best state = 42 Time taken ~ 46 seconds Number of generations ~ 22	Number of edges = 100 Fitness value of best state = 48 Time taken ~ 7 seconds Number of generations ~ 140

- Multi-point mutation

Instead of mutating a single node color from the graph, multiple nodes (2, 3, 4, etc.) are mutated with random different color. However, no much improvements in performance were observed.

### Final Improved Genetic Algorithm

Configuration:

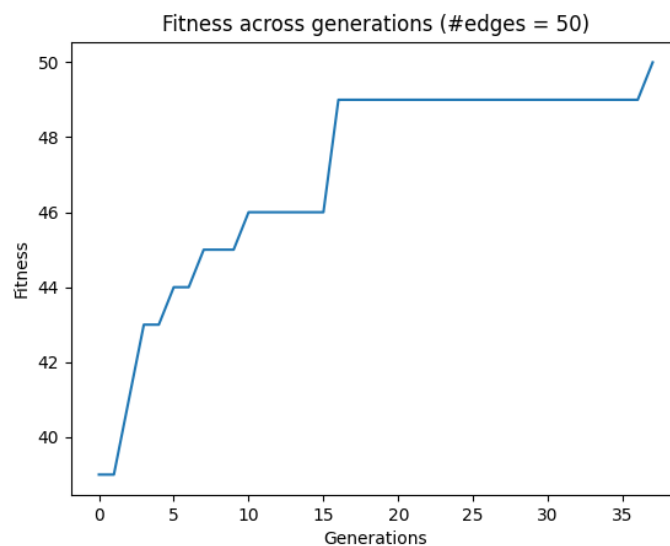
- Population size = 20
- Generation limit = 150
- Generation of 2 children at a time from same parents

Testcase edges = 50

```

Roll no: 2021H1030029G
Number of edges: 50
Best state:
0:G, 1:B, 2:B, 3:R, 4:G, 5:R, 6:B, 7:R, 8:R, 9:R, 10:R, 11:R, 12:B, 13:G, 14:G, 15:B, 16:B, 17:R, 18:G, 19:B, 20:B, 21:G, 22:G, 23:B, 24:G, 25:B, 26:R, 27:R, 28:G, 29:G, 30:G, 31:G, 32:R, 33:G, 34:B, 35:R, 36:G, 37:R, 38:B, 39:B, 40:R, 41:B, 42:R, 43:B, 44:R, 45:R, 46:B, 47:R, 48:G, 49:R
Fitness value of best state: 50
Time taken: 0.94 seconds

```

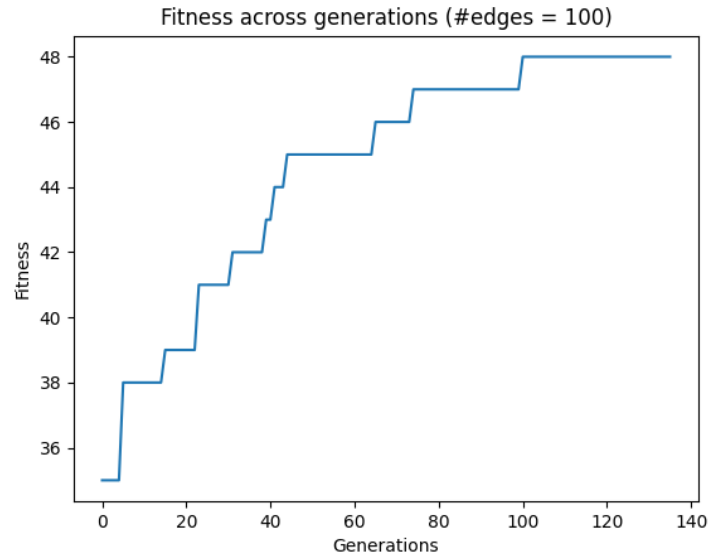


Testcase edges = 100

```

Roll no: 2021H1030029G
Number of edges: 100
Best state:
0:G, 1:R, 2:R, 3:B, 4:B, 5:G, 6:B, 7:R, 8:G, 9:R, 10:R, 11:G, 12:G, 13:G, 14:R, 15:R, 16:R, 17:B, 18:G, 19:R, 20:R, 21:R, 22:G, 23:G, 24:G, 25:R, 26:B, 27:B, 28:B, 29:G, 30:G, 31:B, 32:R, 33:G, 34:G, 35:R, 36:B, 37:G, 38:B, 39:B, 40:B, 41:G, 42:B, 43:B, 44:G, 45:B, 46:R, 47:G, 48:R, 49:B
Fitness value of best state: 48
Time taken: 7.03 seconds

```

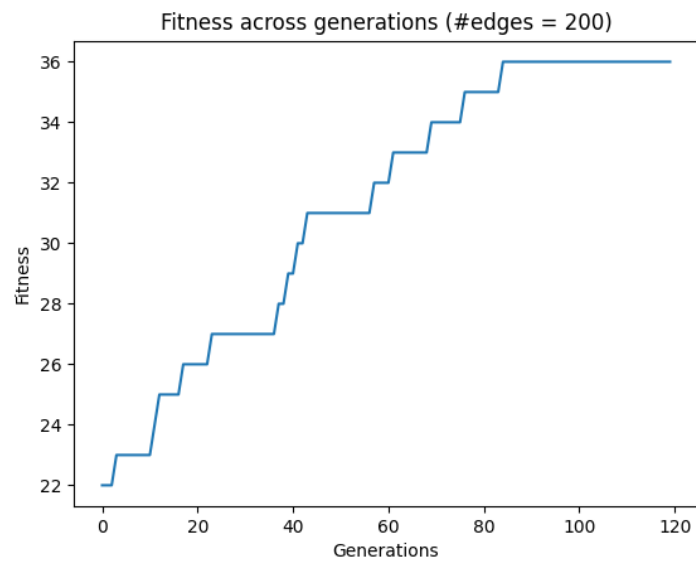


### Testcase edges = 200

```

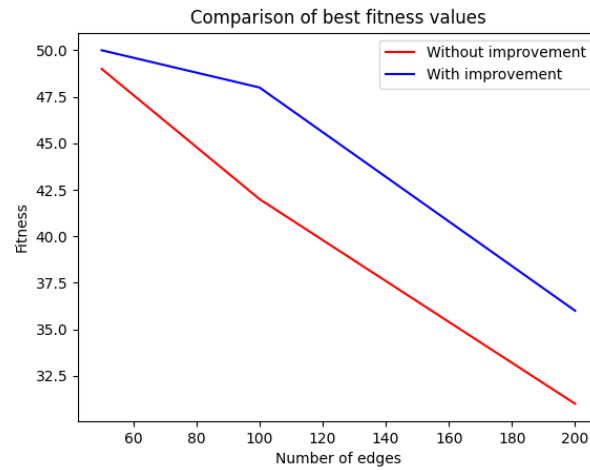
Roll no: 2021H1030029G
Number of edges: 200
Best state:
0:G, 1:G, 2:G, 3:B, 4:G, 5:G, 6:R, 7:B, 8:B, 9:B, 10:R, 11:B, 12:R, 13:B, 14:R, 15:G, 16:G, 17:R, 18:G, 19:G, 20:G, 21:G, 22:G, 23:R, 24:R, 25:R, 26:R, 27:B, 28:R, 29:B, 30:B, 31:B, 32:B, 33:G, 34:G, 35:B, 36:R, 37:B, 38:R, 39:G, 40:B, 41:R, 42:R, 43:R, 44:G, 45:R, 46:G, 47:G, 48:R, 49:B
Fitness value of best state: 36
Time taken: 9.5 seconds

```

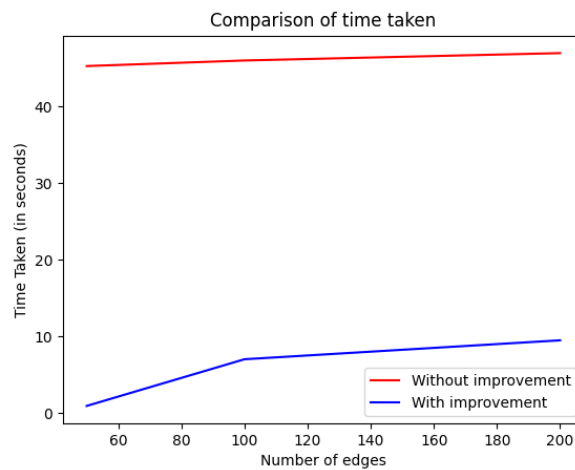


## Comparison between basic and improved algorithm

### 1. Fitness



### 2. Time Taken



### 3. Number of generations

