FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY

BITI 3143
EVOLUTIONARY COMPUTING

PROJECT REPORT

GROUP: S1G2 GROUP 5
PROJECT TITLE: CCTV COVERAGE FOR MUSEUM

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Coding	• Map Design • Population Initialization • Looping • Chromosome Evaluation • Parent Selection	RUSYDI NASUTION BIN RIDUAN
	• Crossover • Mutation • Survival Selection • Print Result	LOO HEN SHEN

2.0 Description of the Problem to Solve

There are so many valuable items in museums that need to keep. So, we need to take care of these valuable items, but it will be difficult for people to keep an eye on them 24 hours. Hence, we need to put surveillance cameras around the museum area. Closed Circuit Television, or CCTV, is a video system that consists of strategically placed video cameras around an area that records footage and is then transmitted to a display monitor for real-time viewing and footage playback. By placing CCTV strategically in museums, valuable items will be safer and easier to monitor. The placement of CCTV is important to optimize the area's sight value and to ensures even sight among all plots in the museum. From figure 1 below shows the good and bad placement of CCTV in the museum.

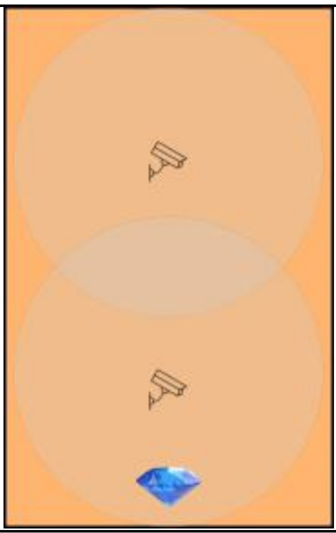
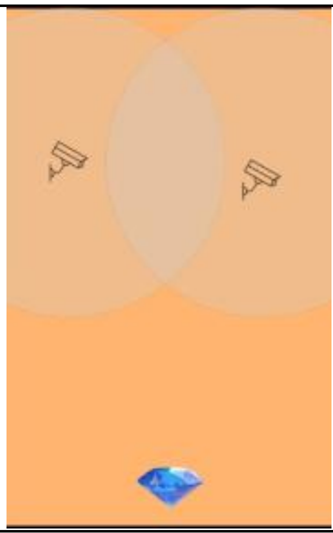
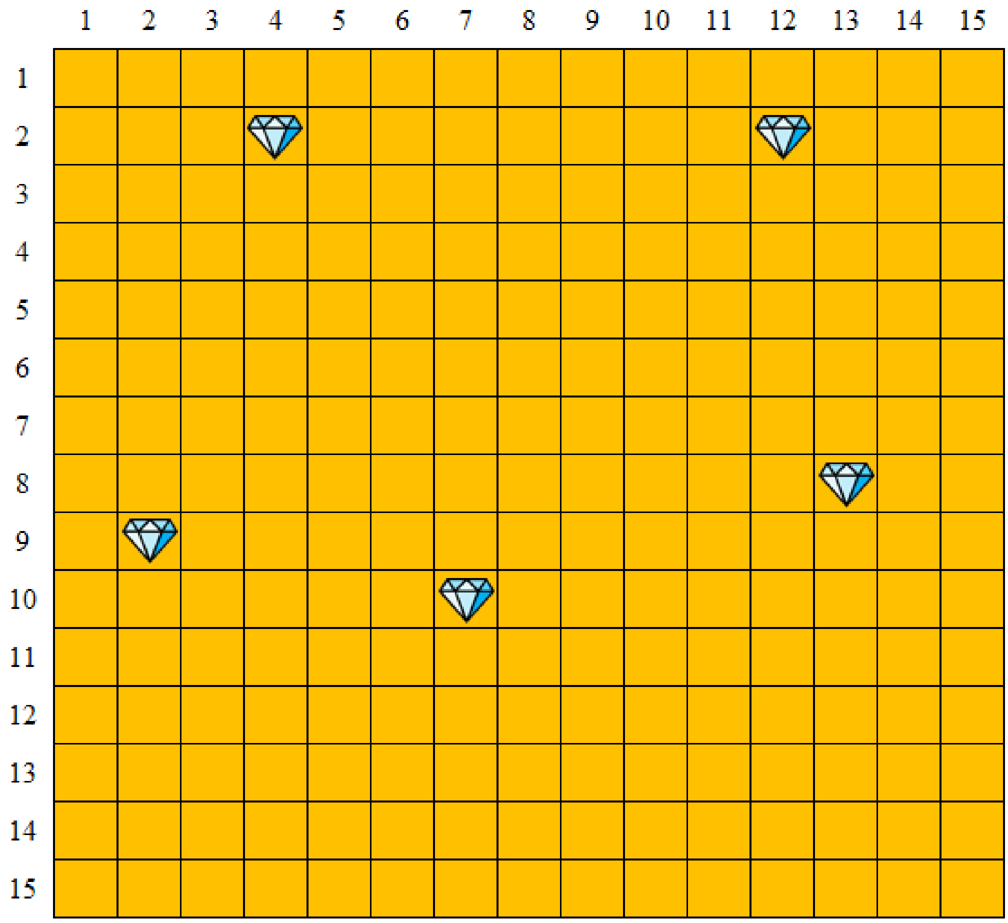
	
Good CCTV Placement	Bad CCTV Placement

Figure 1: Placement of CCTV and valuable item in museum

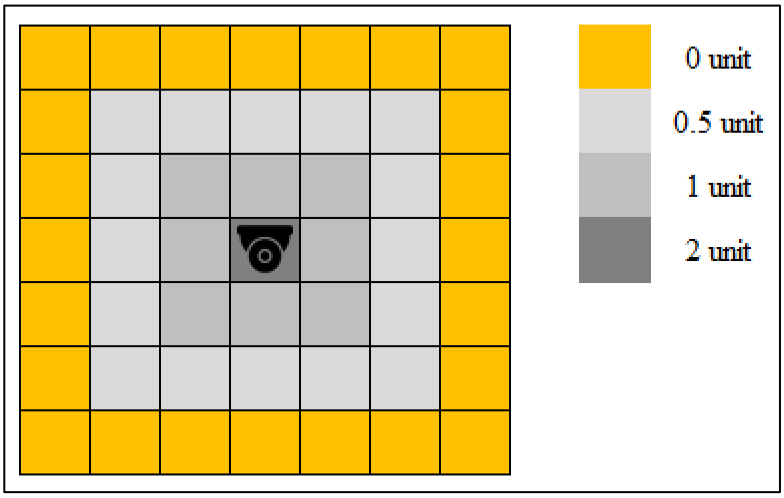
3.0 Description of the Problem's Instances

The problem is based on a museum with a map size of 15 by 15 units. In the museum, there are 5 valuable items placed on the map as shown in Figure 2. It is allowed to use maximum 15 CCTV to have vision over the map. Each CCTV has a circular vision coverage with radius of 2 unit. As shown in Figure 3, grid that contains a CCTV is awarded with 2 vision score, grid that are 1 unit away from a CCTV is awarded with 1 vision score, grid that are 2 unit away from a CCTV is awarded with 0.5 vision score, and grid that are not under coverage of CCTV would have 0 vision score. For grid that are covered by multiple CCTV, the vision score would be the maximum value it can obtain from each individual CCTV. The first objective of this project is to maximize the coverage area of CCTV vision, especially around the grid that are place with a valuable item. The second objective is to minimise the number of CCTV used to reduce the cost.



Legend: - Valuable Item

Figure 2: Placement of Valuable Item in Map of Museum



Legend: - CCTV

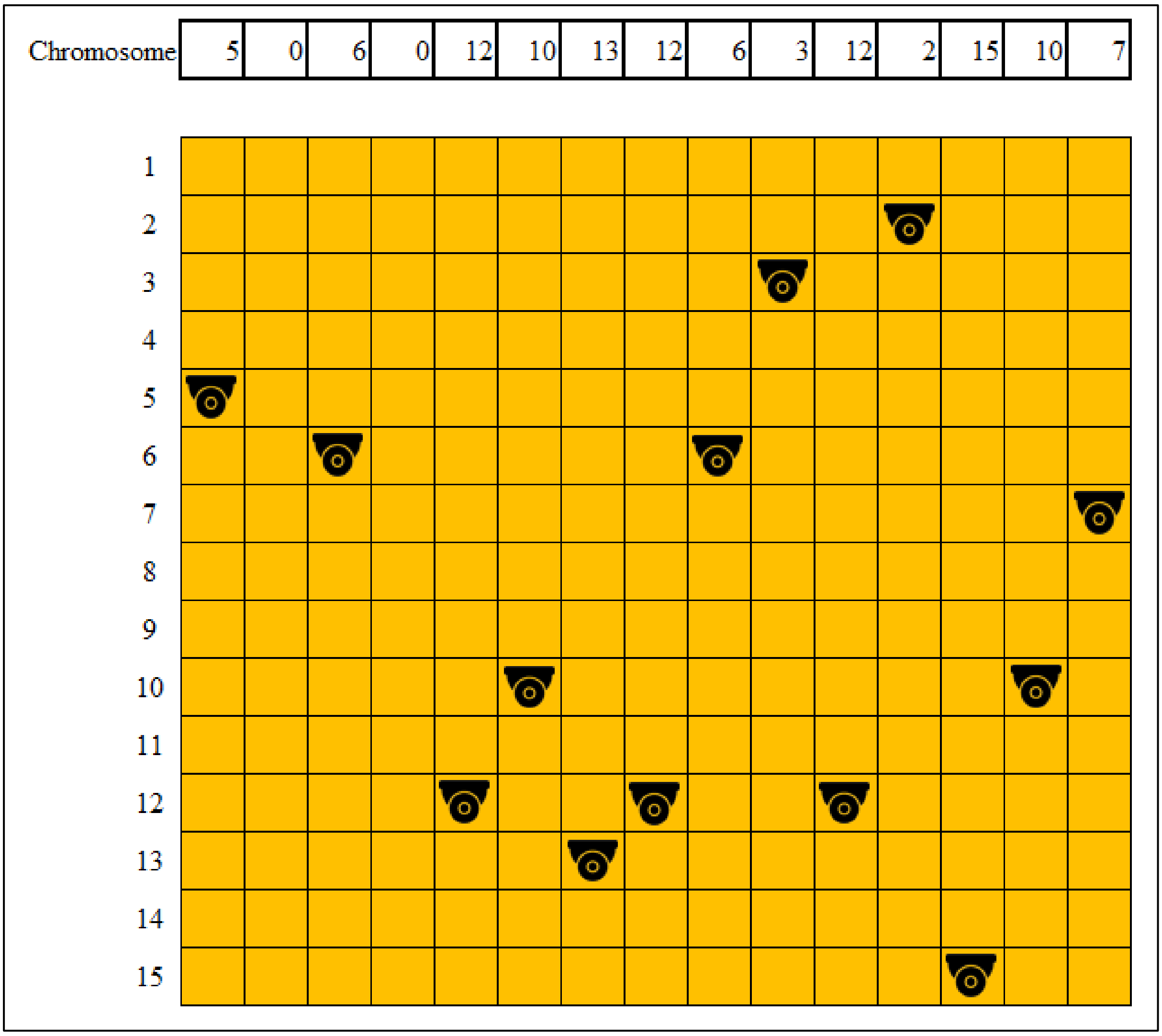
Figure 3: Vision Score Provided by a CCTV

4.0 Detail Description on The GA's Design

4.1 Chromosome Representation

The chromosomes in this project are represented by an integer array with the size of 15 indices. The allele of the chromosome is integer value ranged from 0 to 15, with 0 represents no CCTV is placed on that column, and 1 to 15 represents the row number of the CCTV that is placed on that column. The chromosome is initialized randomly with integer from 0 to 15.

Allele	Representation
0	No CCTV is placed
1	CCTV is placed on row number 1
2	CCTV is placed on row number 2
3	CCTV is placed on row number 3
4	CCTV is placed on row number 4
5	CCTV is placed on row number 5
6	CCTV is placed on row number 6
7	CCTV is placed on row number 7
8	CCTV is placed on row number 8
9	CCTV is placed on row number 9
10	CCTV is placed on row number 10
11	CCTV is placed on row number 11
12	CCTV is placed on row number 12
13	CCTV is placed on row number 13
14	CCTV is placed on row number 14
15	CCTV is placed on row number 15



Legend: - CCTV

Figure 4: Sample CCTV Placement Based on Chromosome

Sample of Initial Chromosome

Chromosome 1	5	0	6	0	12	10	13	12	6	3	12	2	15	10	7
Chromosome 2	4	1	12	5	12	13	10	5	3	11	12	13	1	15	5
Chromosome 3	3	6	12	9	15	8	13	13	0	14	2	15	15	13	8
Chromosome 4	6	1	1	12	10	0	14	1	6	12	7	0	13	14	15
Chromosome 5	15	11	14	14	5	14	6	6	13	5	6	6	9	7	9
Chromosome 6	15	9	7	8	6	13	7	13	9	7	11	11	6	4	15
Chromosome 7	12	8	12	11	11	2	7	6	3	1	3	9	7	14	4
Chromosome 8	5	4	1	11	7	4	12	11	11	4	7	7	0	9	7
Chromosome 9	15	11	14	5	13	13	0	12	11	9	14	3	8	1	11
Chromosome 10	12	11	0	7	11	6	14	13	11	14	15	14	14	10	13

4.2 Fitness Function

The fitness function is calculated based on 2 factors:

1) Vision score of CCTV placement
2) Number of CCTV used

The first factor is the vision score of CCTV placement. A CCTV has a circular vision with radius of 2 units from the centre. Hence, Grid with a CCTV is awarded with a vision score of 2 units, grid which are 1 unit away from the CCTV is awarded with vision score of 1 unit, and finally grid which are 2 units away from the CCTV is awarded with vision score of 0.5 unit. For the grid that are under surveillance of multiple CCTV, its vision score will be the maximum value it can obtained from each CCTV. However, grid that are not covered by any CCTV does not has vision and its vision score will be 0 unit. Besides, the vision score of grids that contains the valuable item will be multiply by 2 to encourage CCTV coverage over the valuable items. Hence, the fitness value 1, f_1 is calculated by sum up the vision score of all grids, and divided by 460, which is 2*(Map Size)^2 + 2*(Number of Valuable Item).

$$f_1 = \frac{\sum Vision\ Score}{460}$$

The second factor is the number of CCTV used. The fitness value 2, f_2 is calculated by taking maximum number of CCTV allowed (15) subtract with the number of CCTV used, then divided by the maximum number of CCTV allowed.

$$f_2 = \frac{15 - (number\ of\ CCTV\ used)}{15}$$

Finally, the final fitness value, f is calculated by taking the sum of $0.75 * f_1 + 0.25 * f_2$ such that f_1 has a higher weightage than f_2.

$$f = f_1 + f_2$$

4.3 Strategy of Parent Selection, Crossover, Mutation and Survival Selection

(a) Parent Selection

The parents are selected by using tournament selection. Firstly, randomly choose 2 candidates and select the candidate with the higher fitness value as the first parent. The process is run again to select another parent. If the second parent is the same as the first parent, the process is repeated until parent 2 is different from parent 1. Tournament selection is used to select the parents as it is efficient to code, and it enables the selection pressure between the population.

(b) Crossover

The crossover operation chosen is uniform crossover. The crossover happens when 2 parents is selected and a random value between 0 to 1 generated is less than the crossover probability. In uniform crossover, parent 1 is assigned as the head of coin and parent 2 is assigned as the tail of coin. When crossover happens, the gene of children 1 depends on the value obtained in the coin flipping. If it is head, children 1 will have the gene of parent 1 and vice versa. After that, the gene of children 2 will inherit from opposite side of children 2.

Parent 1	12	11	0	7	11	6	14	13	11	14	15	14	14	10	13
Parent 2	15	11	14	5	13	13	0	12	11	9	14	3	8	1	11

Children 1	15	11	14	7	11	13	0	13	11	9	14	14	14	1	13
Children 2	12	11	0	5	13	6	14	12	11	14	15	3	8	10	11

(c) Mutation

The mutation operation chosen is swap mutation. A random real number between 0 to 1 is generated. If the real number is less than the mutation probability that are set initially, mutation operation will occur. While mutation happens, 2 random genes in a chromosome are selected randomly. The values of the 2 genes are exchanged to produce a mutated chromosome.

Before mutation

Children 1	15	11	14	7	11	13	0	13	11	9	14	14	14	1	13

After mutation

Children 1	15	11	14	7	14	13	0	13	11	9	11	14	14	1	13

(d) Survival Selection

The survival selection method chosen is all children replace parent. All parent chromosome is removed from the population and replaced by children that are generated through the process as stated as above.

4.4 Termination Strategy

The termination condition in this project is determined by a set maximum generation. The number of maximum generations is set manually before starting. The reproduction of chromosome will be stopped when the number of generations has reached the maximum generation.

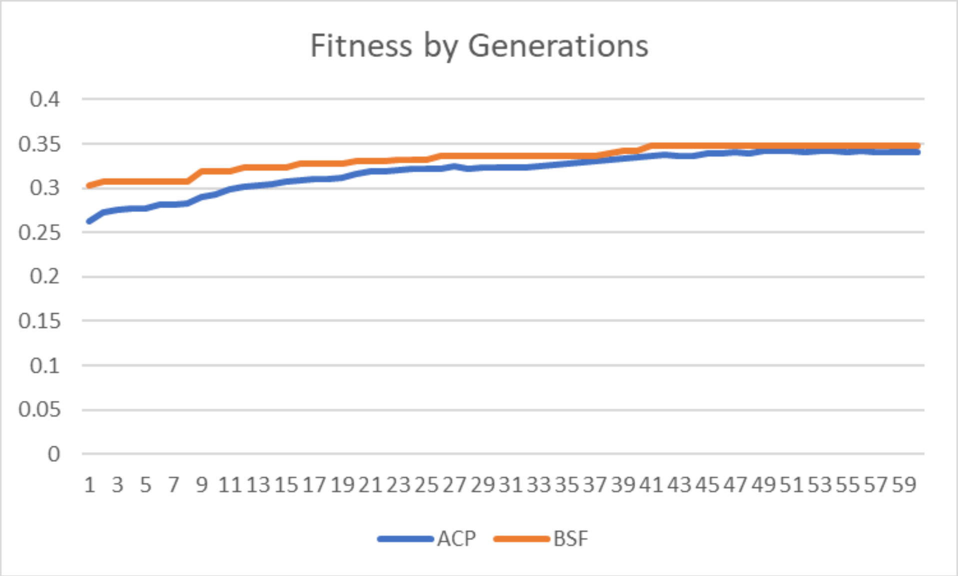
4.5 Measurement Indices

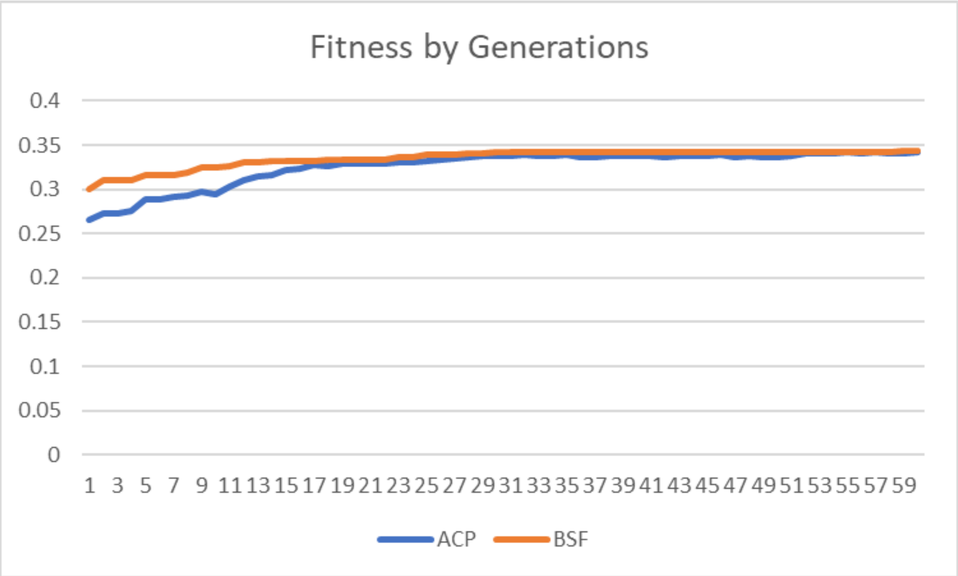
The measurement index in this project is only fitness value. To evaluate the chromosome of each generation in this project, we have used the best fitness so far (BSF) and the average fitness of the current population (ACP). indicates the best fitness value obtain for the current generation while ACP indicates the average value of all chromosomes of the population in current generation only. Generally, BSF is greater than or equal to ACP for every generation.

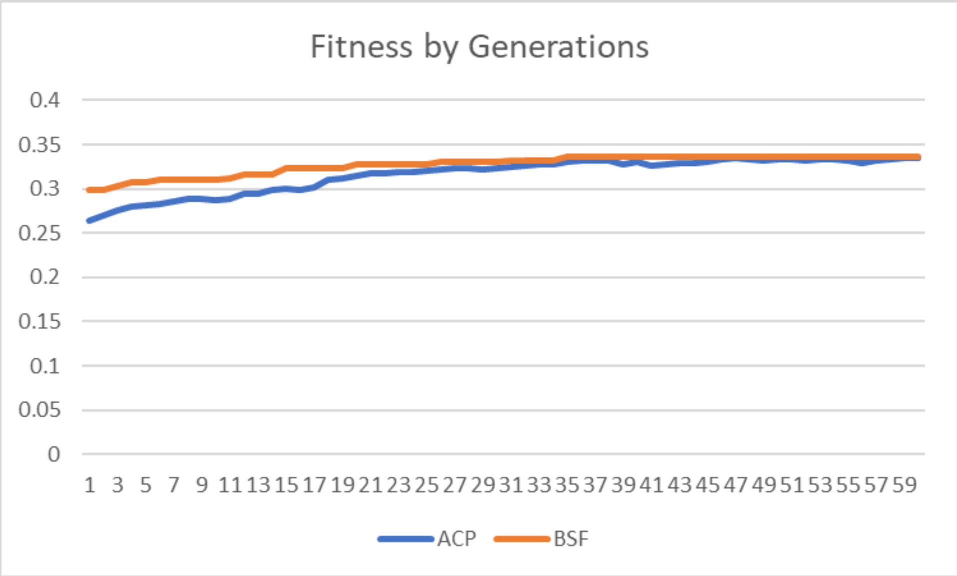
The ACP, BSF, and best chromosome will be recorded into “All_Data.csv” that is generated automatically by the coding. The ACP and BSF is then able to be illustrated in graph to observe the evolving of chromosome.

5.0 The Analysis of Your Result

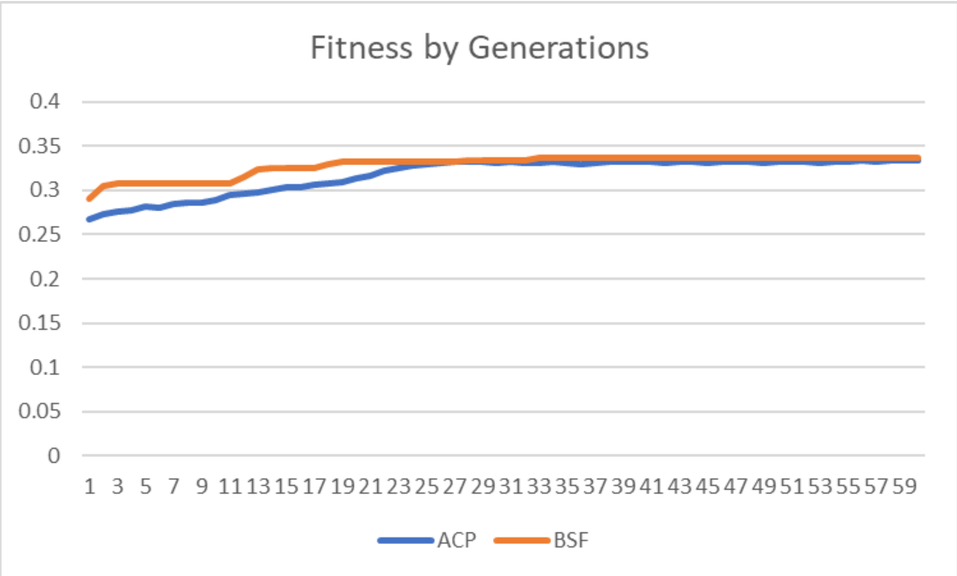
a) 60 Generations with 40 populations size



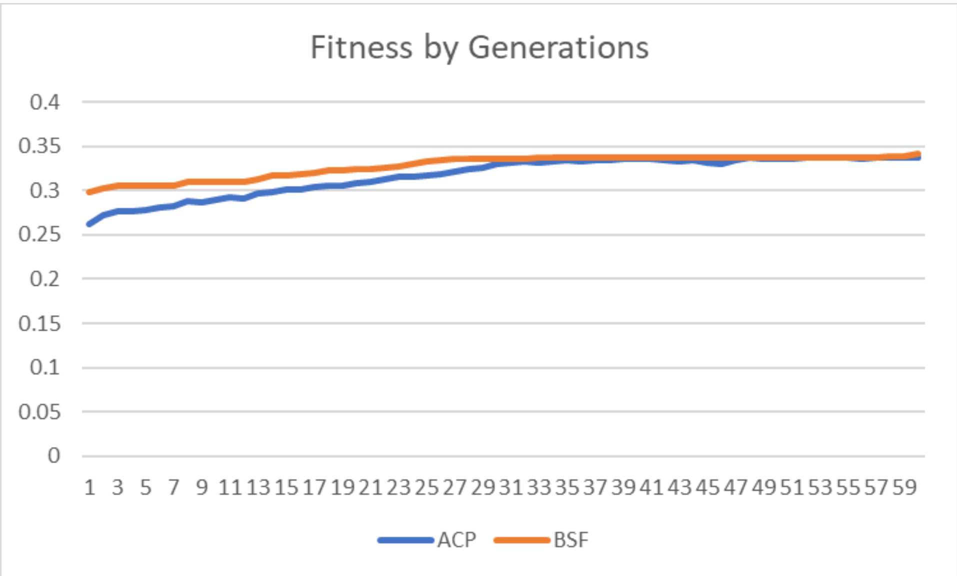




Fitness by Generations
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59
ACP
BSF



Fitness by Generations
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59
ACP
BSF



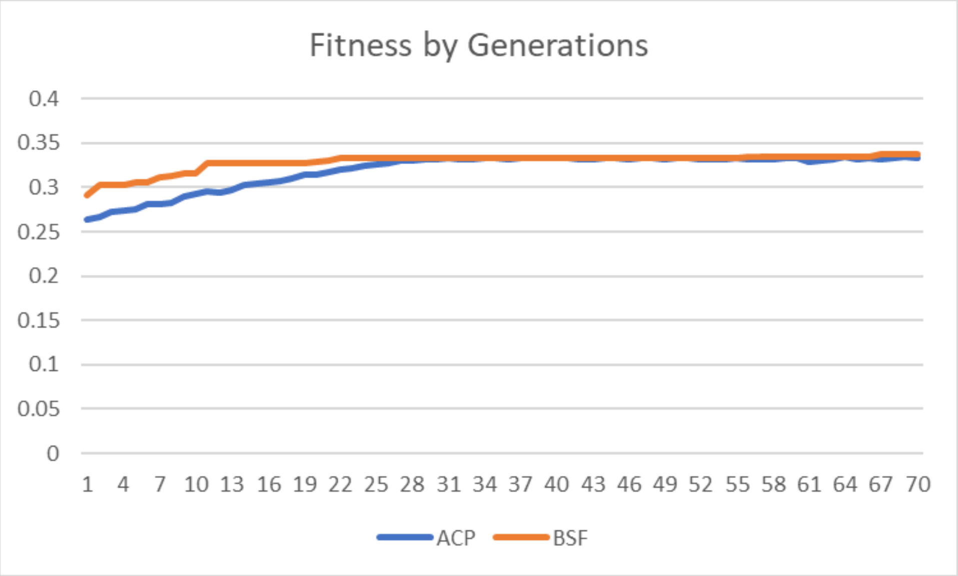
Fitness by Generations
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59
ACP
BSF

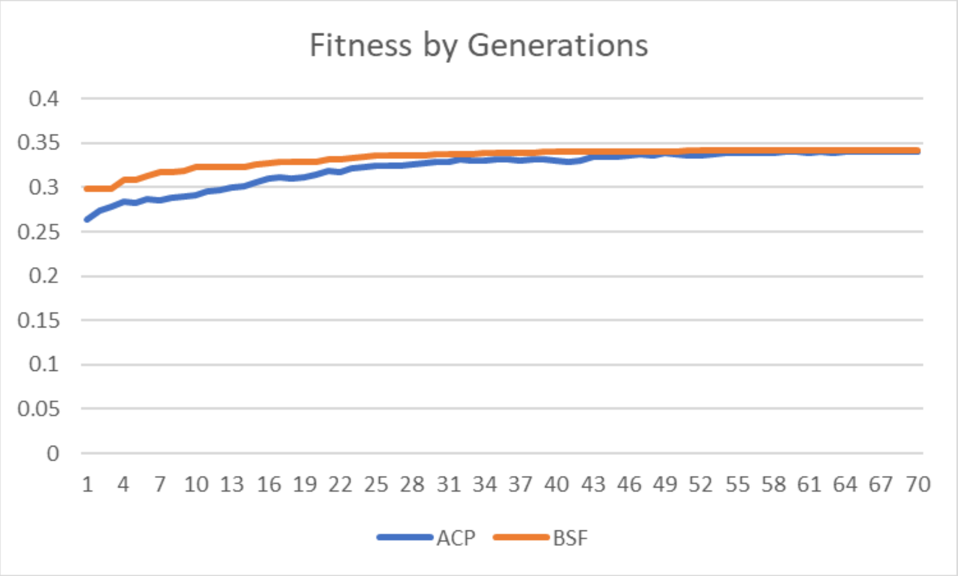
Crossover probability: 0.8

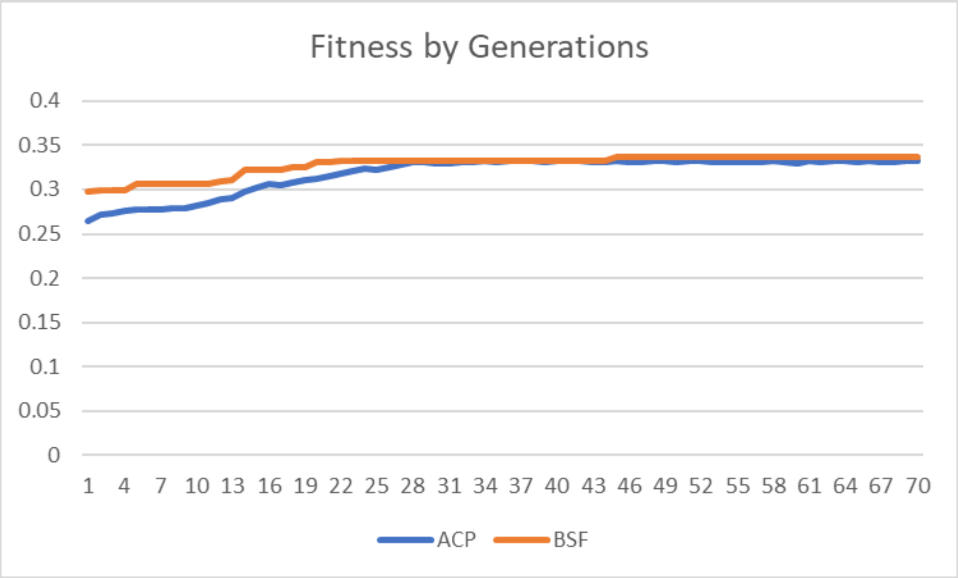
Mutation probability: 0.1

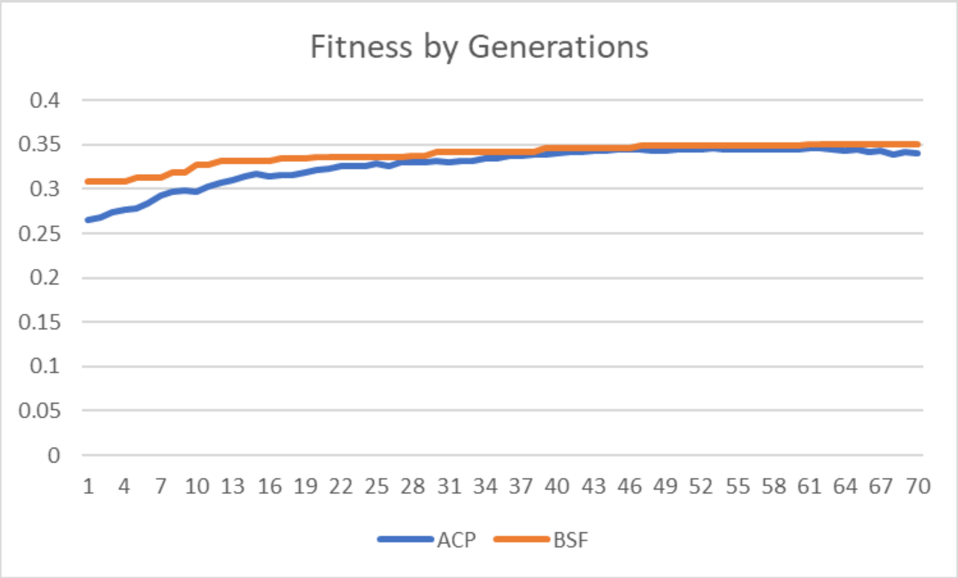
The figure above shows the results fitness of using 60 generations with 40 populations size. As we can see still there is a gap between average fitness and best fitness. The graph also inconsistent. Thus, this result is not the best solution. We need to run again with different generations.

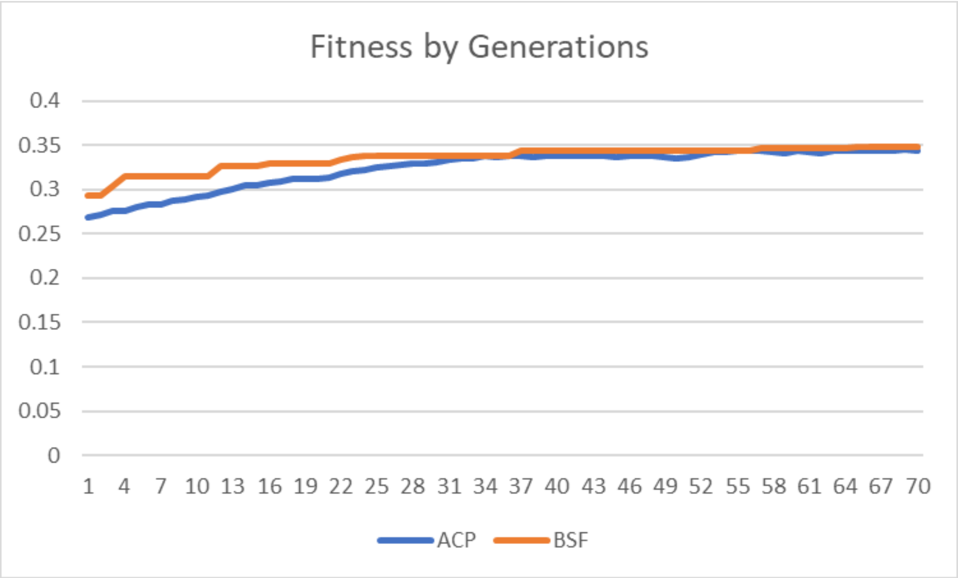
b) 70 Generations with 40 populations size






Fitness by Generations
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70
ACP
BSF


Fitness by Generations
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70
ACP
BSF

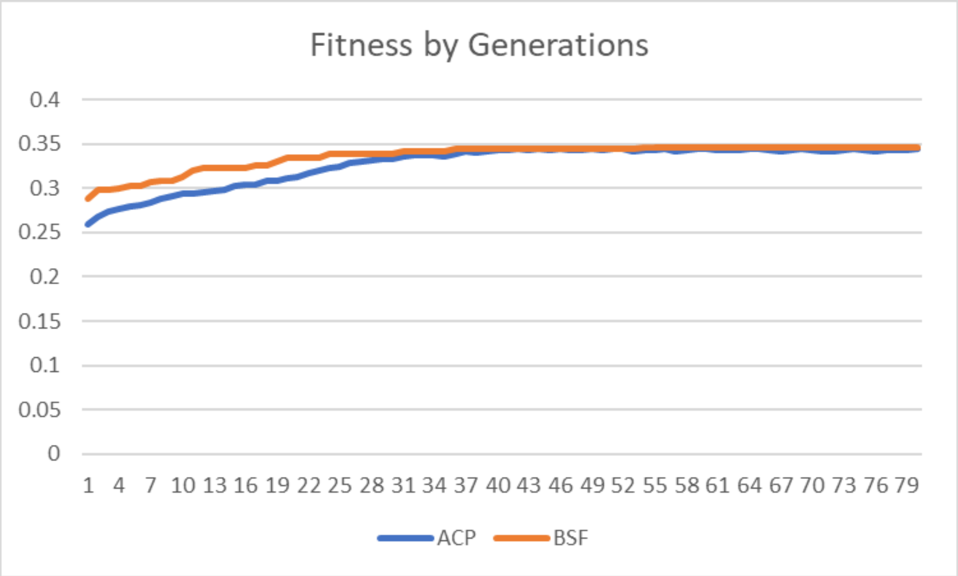

Fitness by Generations
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70
ACP
BSF

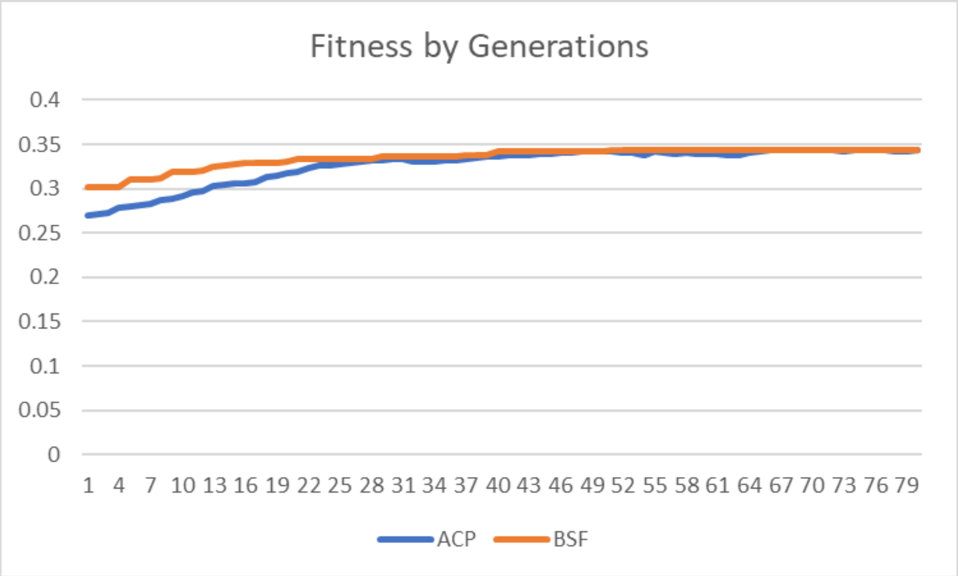
Crossover probability: 0.8

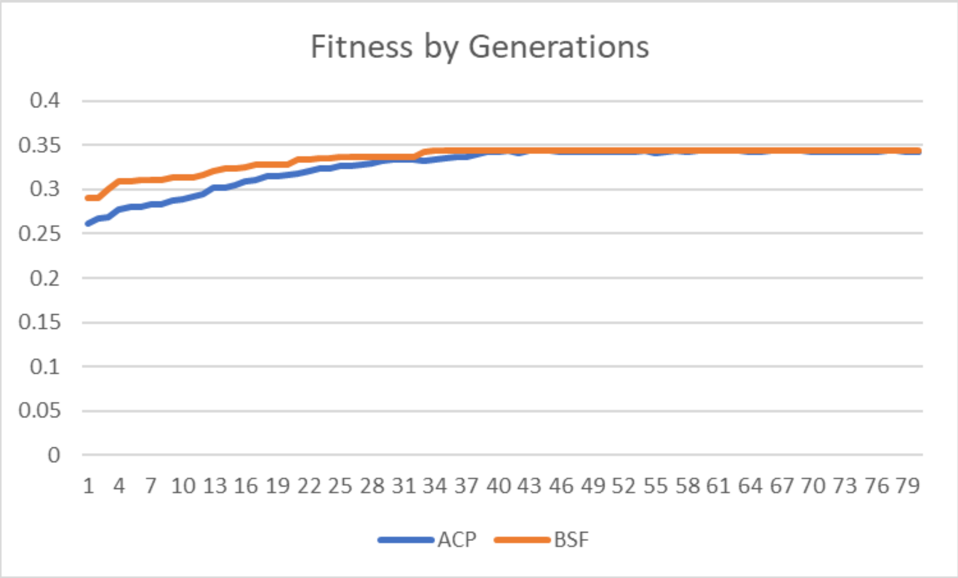
Mutation probability: 0.1

Now we change the generations to 70 and use the same populations as before, 40 populations size. The figure above shows that there is still a gap between average fitness and best fitness. Even if it is just a small gap, does not mean that we have the best evolution of generation. We need to try with the higher numbers of generations again until we found the best solutions.

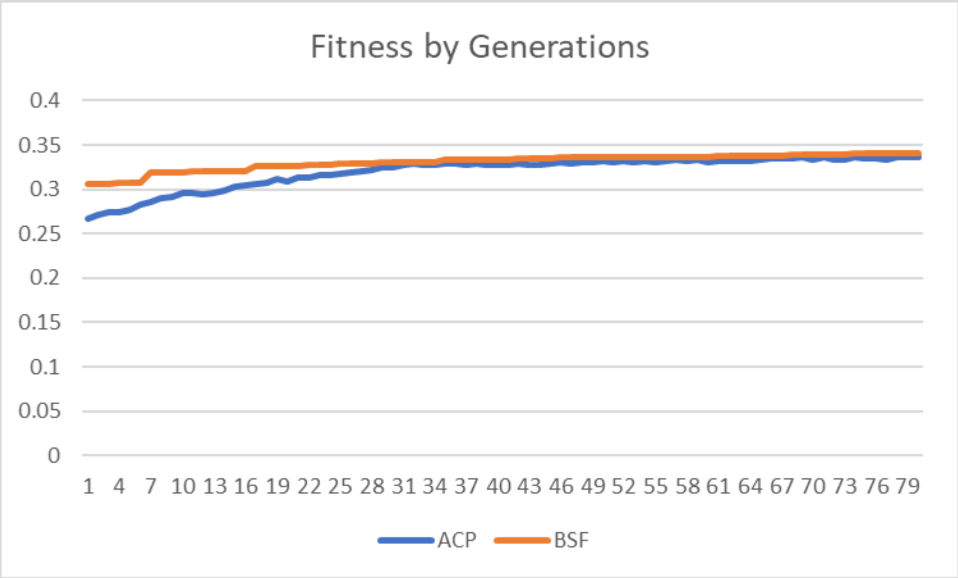
c) 80 Generations with 40 populations size



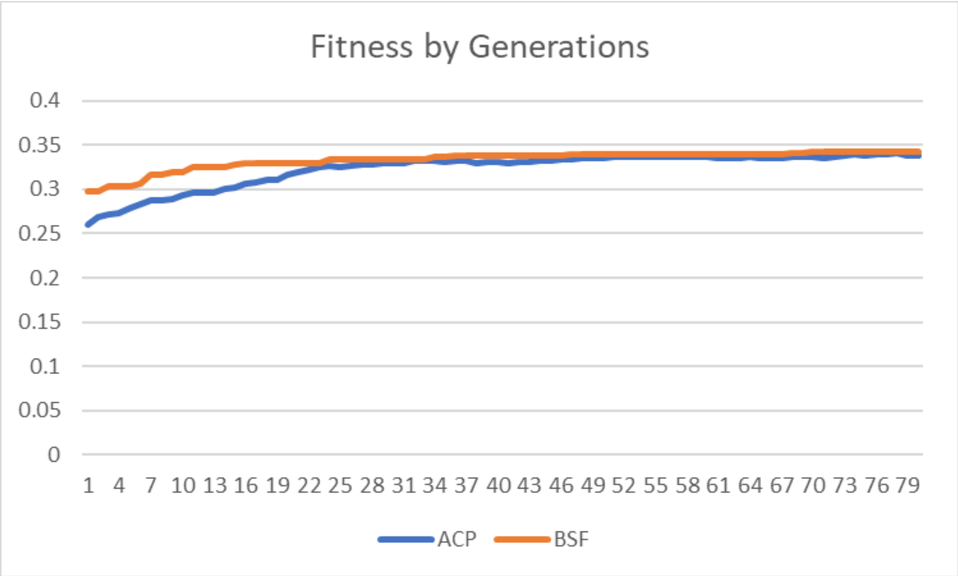




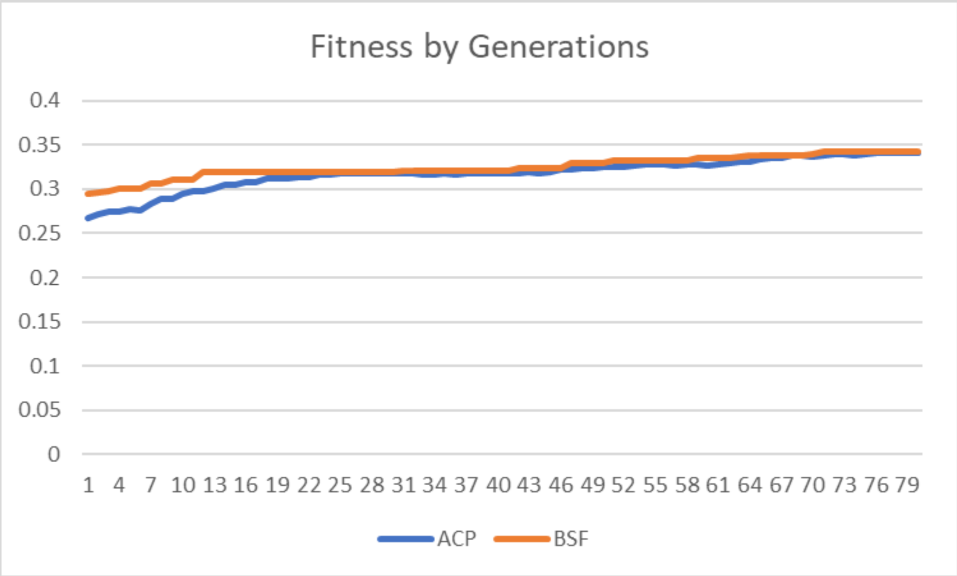
Fitness by Generations
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79
ACP
BSF



Fitness by Generations
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79
ACP
BSF



Fitness by Generations
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79
ACP
BSF



Crossover probability: 0.8

Mutation probability: 0.1

We change the generations to 80 and use the same population as before, 40 population size. As we can see from the figure above, there is no gap between average fitness and best fitness, so it means that we already have best solutions. 80 maximum generations have the best evolving graph.

d) Algorithm Analysis

To test the consistency of the result, we run 10 times and use the parameters: 80 generations, 40 population size, 0.8 crossover rate, and 0.1 mutation rate. The results are in the table below.

Run	Best Fitness	Best Chromosome
1	0.342572	0, 9, 13, 2, 0, 8, 13, 4, 0, 9, 13, 0, 4, 9, 0
2	0.351087	0, 0, 13, 8, 3, 0, 0, 12, 8, 3, 0, 0, 13, 8, 3
3	0.338043	0, 6, 13, 3, 0, 13, 0, 9, 3, 0, 13, 3, 7, 0, 0
4	0.346286	0, 12, 3, 8, 13, 0, 10, 3, 0, 8, 13, 0, 3, 8, 13
5	0.336866	0, 6, 13, 0, 0, 5, 10, 14, 4, 0, 9, 2, 14, 7, 0
6	0.344928	0, 0, 12, 3, 8, 0, 0, 13, 3, 0, 8, 0, 12, 4, 0
7	0.346649	0, 13, 3, 8, 13, 0, 0, 5, 8, 12, 0, 3, 8, 13, 0
8	0.336504	14, 9, 4, 0, 0, 11, 6, 0, 3, 13, 9, 2, 6, 13, 0
9	0.339674	0, 0, 11, 2, 7, 0, 12, 3, 6, 0, 0, 12, 8, 3, 0
10	0.337228	0, 10, 5, 2, 11, 0, 0, 9, 5, 0, 13, 2, 8, 0, 0

e) Best Solution

Valuable Location		0	9	0	2	0	0	10	0	0	0	0	2	8	0	0
Best Chromosome		0	0	13	8	3	0	0	12	8	3	0	0	13	8	3
Vision Score Map		0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
		0	0	0.5	2	1	1	0.5	0.5	1	1	1	1	0.5	1	1
		0	0	0.5	1	2	1	0.5	0.5	1	2	1	0.5	0.5	1	2
		0	0	0.5	1	1	1	0.5	0.5	1	1	1	0.5	0.5	1	1
		0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
		0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
		0	0.5	1	1	1	0.5	0.5	1	1	1	0.5	0.5	1	1	1
		0	0.5	1	2	1	0.5	0.5	1	2	1	0.5	0.5	2	2	1
		0	1	1	1	1	0.5	0.5	1	1	1	0.5	0.5	1	1	1
		0	0.5	0.5	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
		0.5	0.5	0.5	0.5	0.5	0.5	1	1	1	0.5	0.5	0.5	0.5	0.5	0.5
		0.5	1	1	1	0.5	0.5	1	2	1	0.5	0.5	1	1	1	0.5
		0.5	1	2	1	0.5	0.5	1	1	1	0.5	0.5	1	2	1	0.5
		0.5	1	1	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	1	1	0.5
		0.5	0.5	0.5	0.5	0.5	0	0	0	0	0	0.5	0.5	0.5	0.5	0.5
Number of CCTV	9															
Total Value	154/460															
Fitness 1	0.334783															
Fitness 2	0.4															
Total Fitness	0.351087															

Figure 5: Details for Best Chromosome of All Run

This is the best placement of CCTV that we can obtained from the 10 runs that we carried out. It uses only 9 CCTV and manages to cover a large section of the map. Surprisingly, the CCTV is not placed directly on the grid that contains valuable item, which we believe would further increase the fitness value if doing so.