PERFORMANCE OF DIFFERENT OPERATION TECHNIQUES APPLIED IN GENETIC ALGORITHM TOWARDS BENCHMARK FUNCTIONS

BY

ONG CHIN HWA

A REPORT

SUBMITTED TO

Universiti Tunku Abdul Rahman

in partial fulfillment of the requirements

for the degree of

BACHELOR OF COMPUTER SCIENCE (HONS)

Faculty of Information and Communication Technology
(Perak Campus)

JANUARY 2018

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DECLARATION OF ORIGINALITY

I declare that this report entitled "**PERFORMANCE OF DIFFERENT OPERATION TECHNIQUES APPLIED IN GENETIC ALGORITHM TOWARDS BENCHMARK FUNCTIONS**" is my own work except as cited in the references. The report has not been accepted for any degree and is not being submitted concurrently in candidature for any degree or other award.

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Name : ONG CHIN HWA

Date : ________________________

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I would like to express my sincere thanks and appreciation to my supervisor, Dr. Lim Seng Poh who has given me this bright opportunity to engage in Artificial Intelligence related project. For your patience and guidance, unconditional support and love, a million thanks to you.

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ABSTRACT

Optimisation problem becomes a popular topic because it is able to optimise the resources available. The importance of using optimisation in solving the case studies has been revealed by researchers in the past. In addition, Genetic Algorithm (GA) is also become an interesting topic in this highly competitive world as it is able to solve the optimisation problem. However, the performance of GA is always not considered by the researchers due to the limited of knowledge of this area. So, this project aims to analyse different operation techniques in GA and identify the best combination of operation techniques in GA. 4 selection, 3 crossover, 3 mutation and 2 replacement operation techniques are applied and tested using 10 benchmark functions along with different parameters setting. Besides that, number of genes and number of maximum generation are also included in order to explore that whether the parameters setting will affect the performance of GA. Therefore, this project presents the importance on the combinations of different operation techniques in GA. After conducted the experiments, the best operation techniques for each operation was determined respectively. Tournament Selection performs better compared to the others selection operation techniques. Uniform Crossover and Flipping Mutation are the best operation techniques in their operations. The best replacement operation is Weak Parent Replacement. The experimental result shown that GA68 model contains this type of combination. It is concluded that GA68 model is the best GA model compared to the other GA models. Furthermore, this GA model is also able to perform well and obtain a good result when the parameters setting of the optimisation problem have been modified. The result produced from this project is able to assist the researchers to gain a better understanding of GA and apply the appropriate GA model in carrying out their research.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
EC	Evolutionary Computing
SI	Swarm Intelligence
GA	Genetic Algorithm
DE	Differential Evolution
PSO	Particle Swarm Optimisation
TLBO	Teaching Learning Based Optimisation
FA	Firefly Algorithm
PI	Proportional Integral
PMSM	Permanent Magnetic Synchronous Motor
MIMO	Multiple-Input Multiple-Output
IGA	Immune Genetic Algorithm
AIS	Artificial Immune System

Chapter 1 Introduction

1.1 Project Background

Optimisation problem becomes a popular topic and a concerning area to be examined in this highly competitive modern world. This is due to optimisation is able to reduce the cost and maximise the profit of an organisation. Basically, given a function and input within a range of value for the optimisation problems, it can be either in maximisation or minimisation. It will reflect the selection on the best solution towards the problem given. Therefore, optimisation is able to produce the best possible result which is required to increase competitiveness against other competitors. According to Ghose (2002), bracketing methods, region elimination and gradient methods are used to solve the optimisation problem in the mathematical fields. However, these mathematical methods have several weaknesses such as stuck in suboptimal solution, may not be efficient in solving many problems, and also takes longer time to get the optimal solution. In order to overcome these weaknesses, Artificial Intelligence (AI) method is proposed to solve the optimisation problems.

As stated by Sivanandam and Deepa (2008), in the field of computer science, the optimisation problem is always solved using AI methods such as Evolutionary Computing (EC), Evolutionary Strategies, and Swarm Intelligence (SI). This is because AI methods offer several practical advantages including the simplicity, flexibility and robust to dynamic changes. Genetic Algorithm (GA) is one of the popular EC methods used to solve the optimisation problem which is proposed by John Holland in 1975. When GA is used to solve the same optimisation problem, its performances along with the optimal result could be obtained. However, Lim & Haron (2013) have shown that different GA performances and optimal result can be obtained when different operation techniques are applied. Therefore, the result is considered to be the optimal when it is exactly or approximate towards the actual minimum. This method was further developed and now it is useful for solving the complicated optimisation problems such as timetabling and games playing.

1.2 Problem Statement

The main purpose of the optimisation problems is to obtain the best result with the available resources. As stated in the previous section, mathematical methods require longer time to solve the optimisation problems. Thus, GA is applied to simplify the process and handle the optimisation problems. However, most of the previous works only applied GA without considering its performance. As stated by Lim and Haron (2013), the performance of GA are affected when different operation techniques are implemented in GA. Furthermore, as concluded by Reeves and Rowe (2002), the parameters setting is also one of the factors which can affect the performance of GA. In order to find the most appropriate GA to be implemented for a problem, a lot of testing has to be carried out with different combinations of operation techniques and parameters setting. For some of the previous works, the performance of GA is not considered in their case studies. This is due to the authors contain limitation of research time and lack of background knowledge on GA. Therefore, the performance of GA with different combination of operation techniques along with different parameters is explored in this project.

1.3 Project Objectives

This project aims to determine the performance of GA using benchmark functions. The main objectives of this project are intended to accomplish:

1. To analyse different operation techniques in GA.
2. To identify the best combination of operation techniques in GA using benchmark functions along with different parameters setting.

1.4 Project Scope

The scope of this project is stated as follows:

1. Only focus on 4 selection operation techniques, 3 crossover operation techniques, 3 mutation operation techniques and 2 replacement operation techniques. Hence, there are 72 combinations of operation techniques, as known as GA model.
2. Parameter settings (number of genes and number of maximum generation) are considered in this project.
3. The termination criteria applied in this project is maximum generation.
4. 10 benchmark functions as stated in Section 2.10 are used as the fitness functions in this project.
5. C++ programming language is used in this project.

1.5 Impact, Significance and Contribution

As mentioned in the problem statement, the performance of GA is not considered in most of the case studies. This will lead to the case study takes longer time to be completed and may not obtain the best result when the authors are using the inappropriate GA on their case studies. Due to the increasing application of GA in solving the optimisation problem, the performance of GA is an important factor that should be considered. To reduce the consuming time of a research and improve the efficiency of the research, the performance of different GA models must be studied before employing it to the research.

In this project, GA is explored and the best combination of operation techniques in GA is identified. Through this project, the performance of different combinations of operation techniques in GA is determined using benchmark functions. Therefore, the contribution of this project is the result produced can be the reference for the other authors in the future. They can utilise the appropriate GA models to improve the performance of their research.

1.6 Project Organisation

The project organisation is described as follows:

Chapter 2 will introduce GA including the background of GA, flow of GA and the basic operations in GA. In addition, the benchmark functions will be listed as well and some previous works which is related to GA will also be discussed in this chapter.

Chapter 3 will focus on the research methodology of this project and introduce the methods and technologies involved for a clearer view to this project.

Chapter 4 will present the analysis and discussion on the experimental result.

Chapter 5 will conclude the works and results from this project. Future works for this project is also discussed at the end of this chapter.

Chapter 2 Literature Review

2.1 Overview

Nowadays, GA is proved to be one of the effective methods in solving the optimisation problems. As shown in the previous works, GA is able to obtain the good results for different kind of case studies. This chapter is structured as follows: the introduction along with the flow of GA is discussed in the second section. In addition, introduction of benchmark functions is demonstrated. Besides, previous work is thoroughly discussed in the last section.

2.2 Introduction to GA

According to Sivanandam and Deepa (2008), GA was proposed as a heuristic method based on "Survival of the fittest" by John Holland in 1975. This idea was inspired by the theory of natural evolution in the origin of species and it was further developed in the book "Adaptation in natural and artificial systems." Similar to Genetic Programming and Evolutionary Strategy, GA is based on the principle of genetics and evolution. Basically, GA is a stochastic algorithm, it contains randomness in its process as stated by Sivanandam and Deepa (2008).

As stated by Engelbrecht (2002), GA has terms of chromosomes or individuals which represent a solution for the problems. In order to determine the quality of a solution, the solution is evaluated using fitness function and a fitness value is obtained. Generally, fitness function models the optimisation problems. Initial population represents the entire search space of the optimisation problems, has to be generated at the beginning of GA. Several operations including selection, crossover, mutation and replacement, will be performed on the initial population. Based on the work of Lim and Haron (2013), several techniques in each operations can be chosen to be applied in order to meet the conditions of the optimisation problems. The initial individuals will be replaced by the new generated individuals which have a better fitness value. A search termination will be defined to stop the GA and the last generation represents the optimum solution that the GA finds. Hence, the performance of the GA in solving different problems is affected by the techniques applied in each operation. As mentioned by Seng and Gun (2016), the number of parents also affects the performance of Multi-Parent GA. The flow of GA is explored in the next section.

2.3 Flow of GA

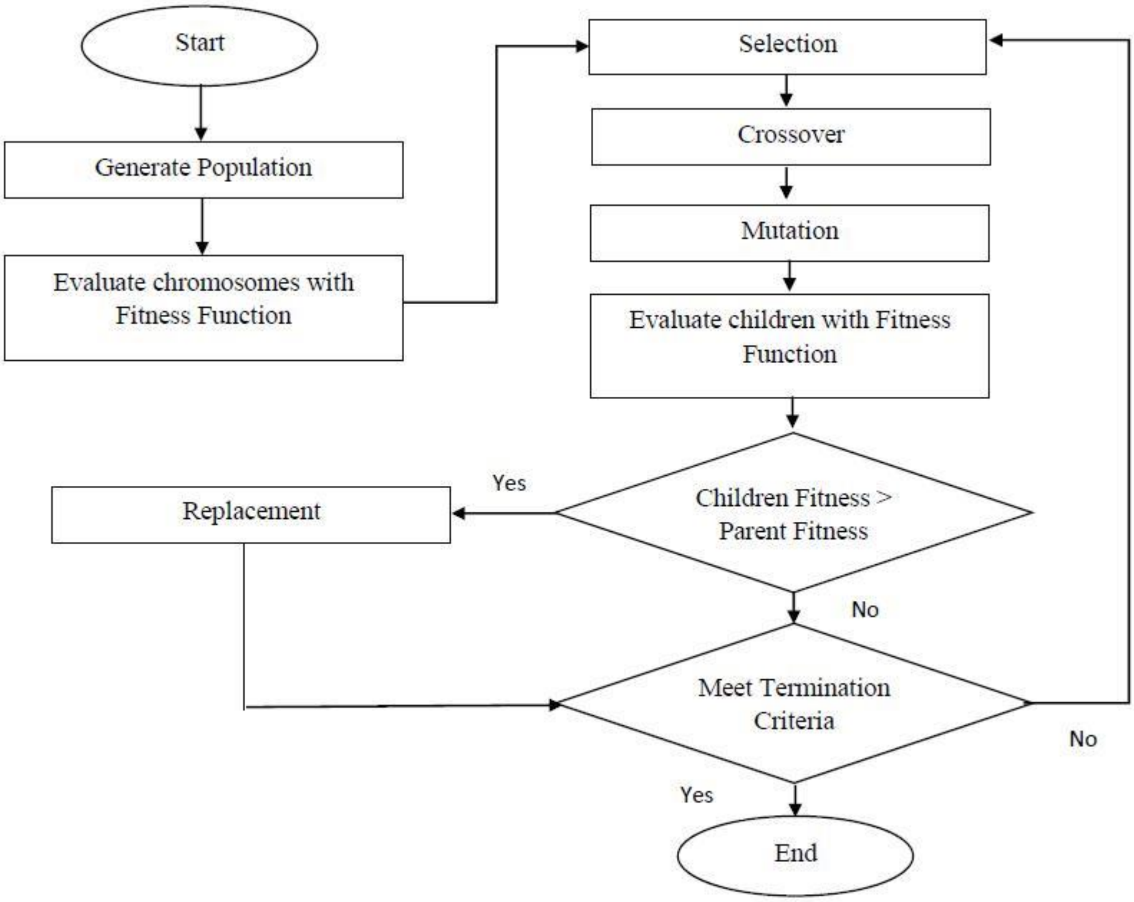


Figure 2.3.1 Flow of Genetic Algorithm

The flow is stated as below:

1. An initial population of chromosomes is generated based on the range given.
2. The chromosomes are then evaluated using the fitness function and the fitness value is determined.
3. In selection, a children is produced by 2 sets of chromosomes which are randomly selected from the population.
4. In crossover, the crossover only happens when a generated random number is less than the crossover probability. Else, the crossover would not happens and proceed to the next operation.
5. In mutation, the mutation only happens when a generated random number is less than the mutation probability. Else, the mutation would not happens and proceed to the next operation.
6. The children are then evaluated using the fitness function.

7. If the children's fitness value is higher than the parents, the parent is replaced by children. Else, check for the termination criteria.
8. If the termination criteria is met, the algorithm is terminated. Else, continue to step 3.

2.4 Selection Operation

According to Sivanandam and Deepa (2008), selection is the process of choosing two individuals (known as parent) from the current population to perform crossover. The selection techniques are used in this project including Roulette Wheel Selection, Random Selection, Rank Selection, and Tournament Selection.

2.4.1 Roulette Wheel Selection

This technique functions similar to the roulette wheel, by assigning a slot to each individual in the roulette wheel, so every individual stands a chance to be chosen as parent. However, the weights of each individual's slot are different, it scales to the individual's fitness value. The higher the fitness value of an individual, the bigger the slot of the individual occupies, and the higher the chance of being chosen as the parent. Figure 2.4.1 illustrates the process of roulette wheel selection.

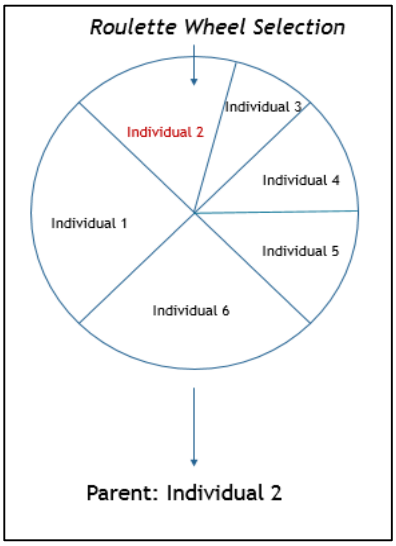
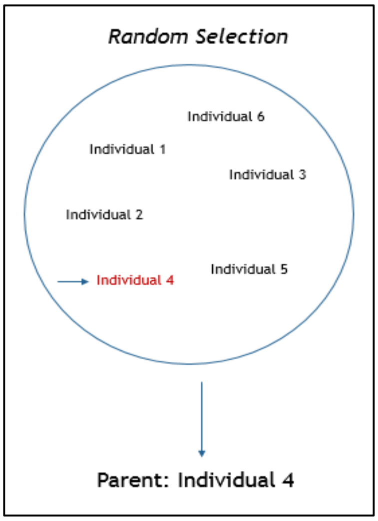


Figure 2.4.1 Roulette Wheel Selection

2.4.2 Random Selection

This technique randomly selects an individual from the population to become the parent without considering the fitness value. Hence, a weak individual could be introduced as the parent by using this technique. Figure 2.4.2 illustrates the process of random selection.



2.4.3 Rank Selection

This technique selects two random individuals from the population. The individual with higher fitness value will be chosen as the parent. Figure 2.4.3 illustrates the process of rank selection.

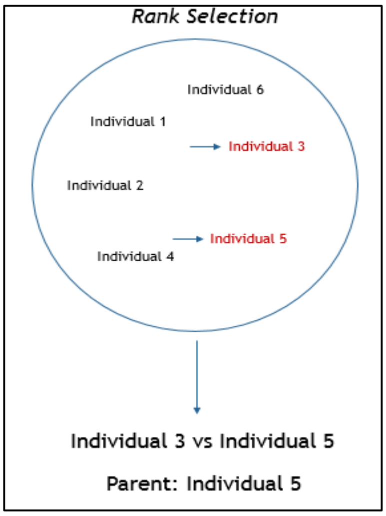


Figure 2.4.3 Rank Selection

2.4.4 Tournament Selection

This technique selects a random number of individual for a competition. The winner of the competition which has the highest fitness value among all the competitors will become the parent. Figure 2.4.4 illustrates the process of tournament selection.

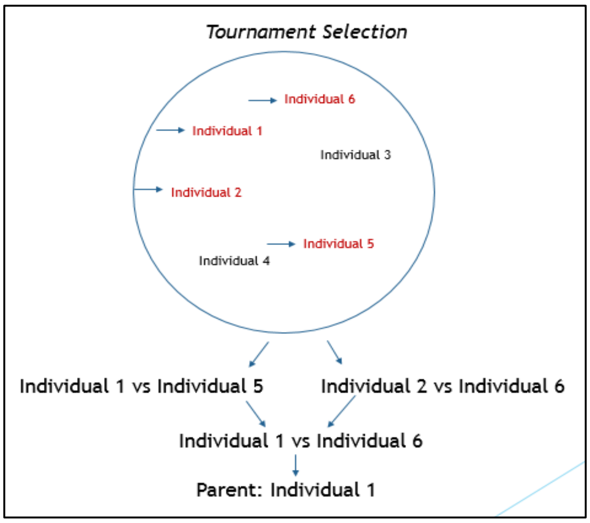


Figure 2.4.4 Tournament Selection

2.5 Crossover Operation

As Sivanandam and Deepa (2008) noted, crossover is the process of taking two parents generated from the selection and producing two individuals (known as child). The crossover happens based on the crossover probability. In this project, Single Point Crossover, Two Point Crossover and Uniform Crossover are used in the crossover operation.

2.5.1 Single Point Crossover

In this technique, a random position along the length of the chromosome is generated and it will be the crossover point. In the chromosome of child 1, the section before the crossover point will be exactly same as parent 1 and the section after the crossover point will be same as parent 2. In the chromosome of child 2, the section before the crossover point will be same as parent 2 and the rest will be same as parent 1. Figure 2.5.1 illustrates the process of single point crossover.

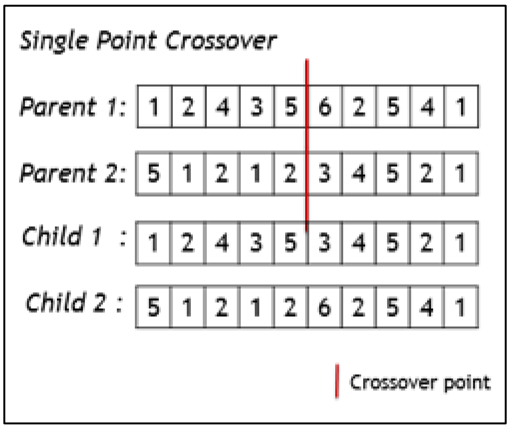


Figure 2.5.1 Single Point Crossover

2.5.2 Two Point Crossover

This technique randomly selects two positions to become the crossover points. The section between the starting point and the first crossover point of child 1 will be copied from parent 1, the section from the first crossover point to the second crossover point will be taken from parent 2, and the section from the second crossover point to ending point will be copied from parent 1. Child 2 works in the opposite way. Figure 2.5.2 illustrates the process of two point crossover.

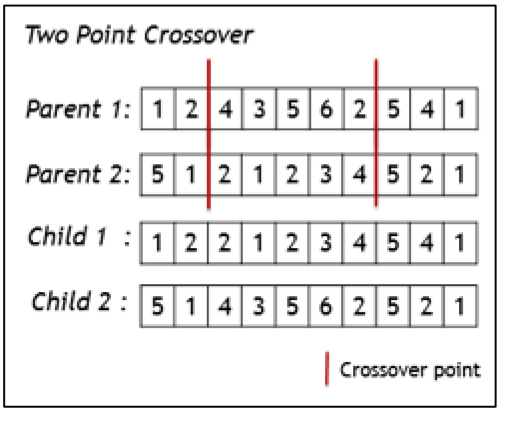


Figure 2.5.2 Two Point Crossover

2.5.3 Uniform Crossover

In this technique, a binary crossover mask is generated. The length of the mask is same as the length of chromosome. If the value of the mask's position is 1, child 1 copies the chromosome from parent 1. Else, child 1 copies the chromosome from parent 2. Child 2 works in the opposite way. Figure 2.5.3 illustrates the process of uniform crossover.

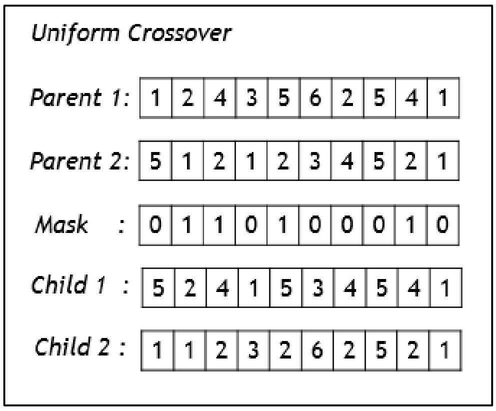


Figure 2.5.3 Uniform Crossover

2.6 Mutation Operation

Sivanandam and Deepa (2008) have concluded that mutation is the process to change the value of an individual's genes to a random value within the range given. The mutation happens based on the mutation probability and the purpose of mutation is to prevent the GA to be trapped in a local minimum. The mutation operations such as Flipping, Interchanging, and Reversing are used in this project.

2.6.1 Flipping

In this technique, a random value is generated in order to replace the old value of a gene. Figure 2.6.1 illustrates the process of flipping mutation.

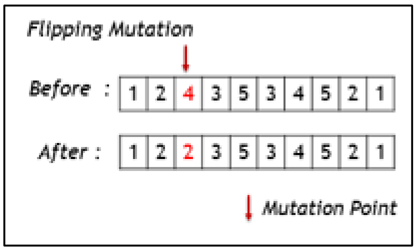


Figure 2.6.1 Flipping

2.6.2 Interchanging

Two different and random genes of the chromosome are selected, and the values of the positions are interchanged. Figure 2.6.2 illustrates the process of interchanging mutation.

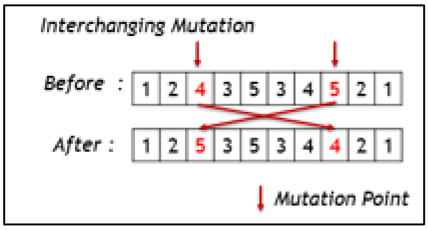


Figure 2.6.2 Interchanging

2.6.3 Reversing

A random gene of the chromosome is chosen, and the value next to that position is reversed. Figure 2.6.3 illustrates the process of reversing mutation.

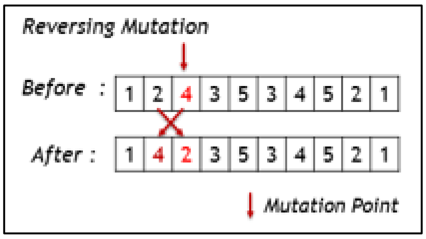


Figure 2.6.3 Reversing

2.7 Replacement Operation

As Sivanandam and Deepa (2008) stated, replacement is the process to return the better fitness value individuals to the population. The purpose of replacement is to ensure the better individuals will be stayed in the population. Random Replacement and Weak Parent Replacement are applied in this project.

2.7.1 Random Replacement

The children replace two randomly chosen individuals in the population without considering the fitness value. Hence, an individual with the higher fitness value may be replaced in this technique. Figure 2.7.1 illustrates the process of random replacement.

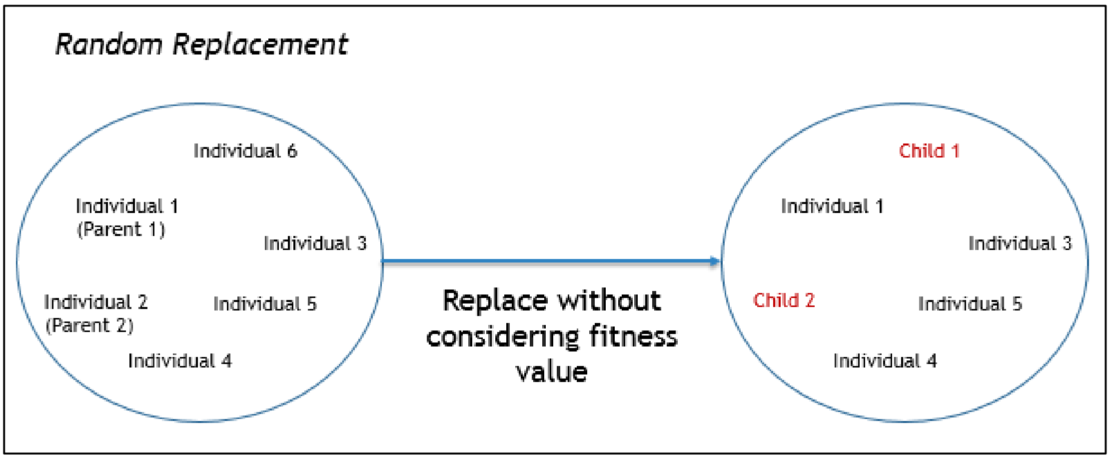


Figure 2.7.1 Random Replacement

2.7.2 Weak Parent Replacement

The children only replace their parent when the parent's fitness value is lower than their children's fitness value. In this technique, the individuals with the lower fitness value will not be inserted into the population. Figure 2.7.1 illustrates the process of weak parent replacement.

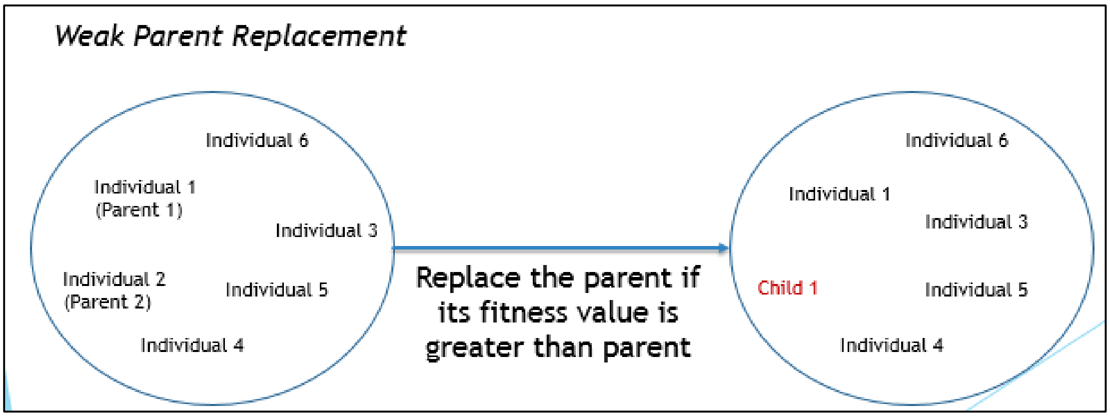


Figure 2.7.1 Random Replacement

2.8 Search Termination

As Sivanandam and Deepa (2008) mentioned, Search Termination is the condition which stops the GA from continue producing new generation. Maximum generation is frequently used as the search termination criteria, as shown in Lim and Haron (2013). Hence, it is applied in this project.

2.9 Parameters in GA

Population size is the total of individuals in the population for one particular generation. Number of genes is the total gene of an individual contains. Figure 2.9.1 illustrates the relationship of population, individual and genes.

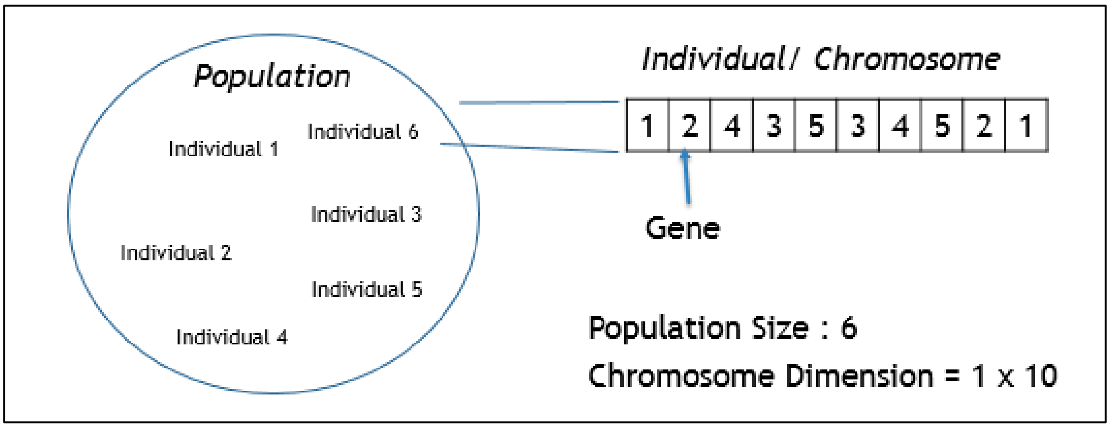


Figure 2.9.1 Population, Individual and Gene in GA

Crossover probability is the probability of a crossover happens in generating new individuals. Mutation probability is the probability of a mutation happens in the genes of an individual. According to Lim and Haron (2013), the suitable crossover probability is 0.7 and suitable mutation probability is 0.01. The reason of high crossover probability is to make the children have more chances to be different from its parents and a better new individual could be generated. The reason of low mutation probability is to preserve the good genes of an individual from changing. Hence, the values mentioned above are used in this project.

In this project, number of generation is the total iteration of performing a whole series of operation techniques. Number of testing is the total of testing for each GA model in optimising every benchmark functions. 30 testing for each GA model in every benchmark functions are performed in this project.

2.10 Benchmark Functions

In this project, 10 benchmark functions are used as the fitness function. These benchmark functions are minimisation problems and they are typical standard functions to test the performance of GA model. As stated by Molga & Smutnicki (2005), the common characteristics of benchmark functions is a single global optimum exists in each benchmark function and some benchmark functions might have huge number of local optimum. Therefore, benchmark functions are good case studies for identifying the performance of GA models in performing optimisation since GA is intended to find the global optimum value. The benchmark functions are referred from the work done by Surjanovic and Bingham (2017) and Lim and Haron (2013). Benchmark functions are stated as follows:

1. Ackley function

$$f(x) = 20 + \exp(1) - 20\exp\left(-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2}\right) - \exp\left(\frac{1}{n}\sum_{i=1}^{n}\cos(2\pi x_i)\right) \quad (1)$$

$-30 \leq x_i \leq 30, i = 1, \ldots, n$

Global minimum, $f(x) = 0$ for $x_i = 0, i = 1, \ldots, n$

n is the number of dimension

2. Axis parallel hyper-ellipsoid function

$f(x) = \sum_{i=1}^{n} i x_i^2$ (2)

$-5.12 \leq x_i \leq 5.12, i = 1, \dots, n$

Global minimum, $f(x) = 0$ for $x_i = 0, i = 1, \dots, n$

n is the number of dimension

3. Sum of different powers function

$f(x) = \sum_{i}^{n} |x_i|^{i+1}$ (3)

$-1 \leq x_i \leq 1, i = 1, \dots, n$

Global minimum, $f(x) = 0$ for $x_i = 0, i = 1, \dots, n$

n is the number of dimension

4. Rotated hyper-ellipsoid function

$f(x) = \sum_{i=1}^{n} \sum_{j=1}^{i} x_j^2$ (4)

$-65.536 \leq x_i \leq 65.536, i = 1, \dots, n$

Global minimum, $f(x) = 0$ for $x_i = 0, i = 1, \dots, n$

n is the number of dimension

5. Sphere function

$f(x) = \sum_{i=1}^{n} x_i^2$ (5)

$-5.12 \leq x_i \leq 5.12, i = 1, \dots, n$

Global minimum, $f(x) = 0$ for $x_i = 0, i = 1, \dots, n$

n is the number of dimension

6. Rastrigin function

$f(x) = 10\, n + \sum_{i=1}^{n} (x_i^2 - 10\ \cos(2\pi x_i))$ (6)

$-5.12 \leq x_i \leq 5.12, i = 1, \dots, n$

Global minimum, $f(x) = 0$ for $x_i = 0, i = 1, \dots, n$

n is the number of dimension

7. Zakharov function

$f(x) = \sum_{i=1}^{n} x_i^2 + (\sum_{i=1}^{n} 0.5x_i)^2 + (\sum_{i=1}^{n} 0.5x_i)^4$ (7)

$-5 \leq x_i \leq 10, i = 1, \ldots, n$

Global minimum, $f(x) = 0$ for $x_i = 0, i = 1, \ldots, n$

n is the number of dimension

8. Schwefel22 function

$f(x) = \sum_{i=1}^{n} |x_i| + \prod_{i=1}^{n} |x_i|$ (8)

$-10 \leq x_i \leq 10, i = 1, \ldots, n$

Global minimum, $f(x) = 0$ for $x_i = 0, i = 1, \ldots, n$

n is the number of dimension

9. Griewank function

$f(x) = \sum_{i=1}^{n} \frac{x_i^2}{4000} - \prod_{i=1}^{d} \cos\left(\frac{x^i}{\sqrt{i}}\right) + 1$ (9)

$-600 \leq x_i \leq 600, i = 1, \ldots, n$

Global minimum, $f(x) = 0$ for $x_i = 0, i = 1, \ldots, n$

n is the number of dimension

10. Quartic with noise function

$f(x) = \sum_{i=1}^{n} ix_i^4 + random[0,1)$ (10)

$-1.28 \leq x_i \leq 1.28, i = 1, \ldots, n$

Global minimum, $f(x) = 0$ for $x_i = 0, i = 1, \ldots, n$

n is the number of dimension

2.11 Previous Works

According to Lim and Haron (2013), different GA methods contain its advantages and limitations while dealing with the problems. It is concluded that none of the GA methods can perform perfectly on every problems. In this work, the performance of 2 GA with different operation techniques was compared using the 5 benchmark functions and it provided a detailed report regarding the experimental result. However, it is not enough to conclude the performance of 2 GA models by only implementing 5 benchmark functions. According to the result from this previous work, GA is proved to perform well in the optimisation problems but the performance highly depends on the applied techniques in each operation.

Another work from the previous two authors, Lim and Haron (2013), compared the performance of GA, Differential Evolution (DE) and Particle Swarm Optimisation (PSO) towards benchmark functions. In this work, it proved that different results are obtained by different methods even though the parameters setting is same. This work applied 3 different methods towards the benchmark functions and compared them in details. However, the result are unable to justify the performance of GA because it is compared with different types of methods.

Ebraheem and Jyothsna (2015) carried out the comparison of performance of teaching learning based optimisation (TLBO) against GA on benchmark functions. TLBO is a consistent optimisation algorithm which is proposed by Rao et al. in 2011. *'The TLBO method is based on the effect of influence of a teacher on the output of learners in the class'* (Ebraheem and Jyothsna, 2015). Similar to the previous work mentioned above, the result is not able to justify the performance of GA because it compared GA with TLBO instead of among different operation techniques of GA. However, the result of comparing GA with TLBO is well obtained through this work and it concluded that TLBO performs better and obtains result faster than GA.

As suggested by Madhu et al. (2016), GA can be applied for minimisation of execution time for cloudlets through optimal allocation of virtual machines. To ensure availability and reliability of services provided by the cloud services provider, the virtual machines have to be placed in different location. Hence, GA is used to optimise the allocation of the virtual machines. In this work, the roulette wheel selection and tournament are used as the selection techniques. However, only one operation technique from crossover, mutation and replacement operation were applied and the relevant techniques were not mentioned. This limits the optimisation problem from getting the most optimal result while only one combination of GA is considered.

Bazi, Benzid, and Nait Said (2017) have applied GA and Firefly Algorithm (FA) to find the optimised proportional integral (PI) controller design in permanent magnetic synchronous motor (PMSM). In this case study, there is a limitation of GA encountered which is trapping in a local minimum. This degrades the performance and reduces the search capability. Furthermore, FA produces more accurate results and takes less computation time. However, the details of operation techniques of both algorithm were not clearly mentioned in this case study. Based on the result, they concluded FA is better than GA from the aspects of time computing, results quality and robustness.

According to the work done by Du, Li and Xu (2016), GA is used to resolve antenna selection for massive multiple-input multiple-output (MIMO) system. MIMO is a technique in 5G and it can produce higher power efficiency than 4G. Hence, the MIMO will be widely implemented in different location. However, the cost of implementing a new MIMO is expensive. Therefore, antenna selection becomes an important issue for reducing the cost while maintaining the performance of the system. In this work, GA is proved to perform well, faster and more practical than other exhaustive method. However, the fitness function was only tested by one GA, so it was not tested by other operation techniques than proposed GA. The performance of other GA could be better than the proposed. In order to get the optimum result for this problem, the combinations of GA operation techniques have to be applied as much as possible.

GA is used in the work of Badge and Gurjar (2016) to recognise the free handwritten style in Marathi script. In this related work, it included image acquisition, image preprocessing, feature extraction, classification and GA. The purpose of this work is to compare the performance of existing techniques with GA. Similar to the previous work mentioned, only one GA was applied to solve the problem. However, the work stated that the optimality of the results obtained using GA is affected by the population and number of iteration. Furthermore, the issues of applying GA included finding a suitable type of representation which is either binary coding or value coding, creating the right fitness function, choosing appropriate combination of GA operation techniques and the specific probability value for crossover and mutation.

As suggested by Boonyopakorn and Meesad (2017), GA is used to solve university time table problems. Generally, the problems of this previous work included allocations and distribution of resources to different task related to different constraints. The operation techniques were performed are tournament techniques as the selection, uniform crossover as the crossover operation, and the chromosome only mutates to a chromosome exactly same as a random existing and valid parent. In addition, this previous work applied four different methods which are GA, Immune Genetic Algorithm (IGA), Particle Swarm Optimisation (PSO) and Artificial Immune System (AIS), and combined them as a hybrid approach to solve the timetabling problem. The authors combined the strengths of each method through hybrid approach. Their work proved that the hybrid approach was able to improve the quality of initial solutions and provide a nearly optimal solution. However, there were only one technique applied in each operation, this limited the performance of the experiment, and the best combination of operation techniques which should be applied in this case study might be ignored.

Most of the previous works show that GA is suitable to be applied in different types of case studies. When GA is incorporated in the case study, it is able to produce the optimum result. However, those previous works do not consider on the performance of the GA. Actually the techniques in each of the operation can affect the overall result of GA, no matter in terms of minimisation or maximisation. Therefore, this project focuses on the performance of GA with different combinations of operation techniques using benchmark functions.

2.12 Summary

This chapter explored the background of GA along with the benchmark functions. Different previous works were discussed in order to understand how GA is incorporated with the case studies. Therefore, 10 benchmark functions are used in this project as the fitness function and tested with different combinations of GA. The result produced from the testing phase is analysed in order to make comparison among the different operation techniques.

Chapter 3 Research Methodology

3.1 Overview

Research methodology helps to identify the main stages of the research. A good research methodology addresses potential issues in research and helps the researchers to coordinate and focus the research effort. This chapter will discuss the methodology of this project.

3.2 Research Framework

The research framework as shown in Figure 3.2.1 is applied in this project described as follows.

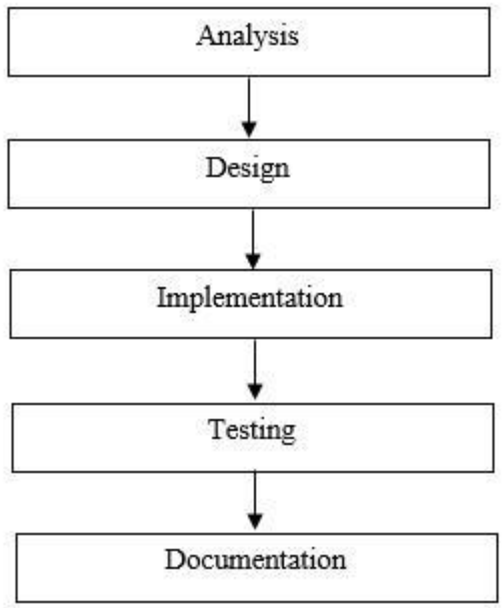


Figure 3.2.1 Research Framework

The main outcome of this project is to propose a good combination of GA operation techniques by comparing the performance of different combinations of GA operation techniques towards the benchmark functions. In addition, two extra experiments with different parameters setting are conducted to provide further justification to the performance of GA models. In order to compare the performances among the GA, a lot of coding and testing are performed. The duration of this project is approximately 20 weeks.

3.2.1 Analysis Phase

Analysis phase is the very first and crucial stage of this project. In analysis phase, the GA concepts, parameters in GA and benchmark functions are studied. In addition, the data collection is conducted during this phase and the data are intended to be randomly generated based on the range of the benchmark functions. To explore the existing solutions and determine the strengths and weaknesses of them, the reviews on the related works of this project are carried out. After reviewing the related works, the project objectives and scopes are defined as the guidelines of this project.

3.2.2 Design Phase

The design phase is carried out by designing and developing the code for the project. In this phase, the operation techniques of GA are further explored and new requirements or constraints are defined. For example, a new requirement which is number of generation changes in different experiments. In addition, the hardware and software specifications, and technology framework are identified in the design phase. In this project, MS Visual Studio 2015 is used to perform experiment with C++ programming language.

This section discusses on the details of GA models and parameters setting. As mentioned in the previous chapter, there are 4 selection operation techniques, 3 crossover operation techniques, 3 mutation operation techniques and 2 replacement operation techniques in this project. Table 3.2.2.1 shows the operation techniques in this project.

No.	**Selection**	**Crossover**	**Mutation**	**Replacement**
1.	Roulette Wheel	Single Point	Flipping	Random
2.	Random	Two Point	Interchanging	Replacement
3.	Rank	Uniform	Reversing	
4.	Tournament			

Table 3.2.2.1 Operation Techniques in GA

In this project, there are 72 combinations of operation techniques are tested towards the benchmark functions. Table 3.2.2.2 shows example for the combination of operation techniques. The complete table has been displayed in Appendix A.

GA model	Selection				Crossover			Mutation			Replacement	
	Roulette Wheel	Random	Rank	Tournament	Single Point	Two Point	Uniform	Flipping	Interchanging	Reversing	Random	Weak Parent
GA01	✔				✔			✔			✔	
GA02	✔				✔			✔				✔
GA03	✔				✔				✔		✔	
GA04	✔				✔				✔			✔
GA05	✔				✔					✔	✔	
GA06	✔				✔					✔		✔
GA07	✔					✔		✔			✔	
GA08	✔					✔		✔				✔
GA09	✔					✔			✔		✔	
GA10	✔					✔			✔			✔
GA11	✔					✔				✔	✔	
GA12	✔					✔				✔		✔
GA13	✔						✔	✔			✔	
GA14	✔						✔	✔				✔
GA15	✔						✔		✔		✔	
GA16	✔						✔		✔			✔
GA17	✔						✔			✔	✔	
GA18	✔						✔			✔		✔
GA19		✔			✔			✔			✔	
GA20		✔			✔			✔				✔
GA21		✔			✔				✔		✔	
GA22		✔			✔				✔			✔

Table 3.2.2.2 Example of GA Models with Combinations of Different Operation Techniques

As shown in Table 3.2.2.2, GA1 model consists of roulette wheel selection, single point crossover, flipping mutation and random replacement.

In this project, there are 6 parameters which manipulates the result of testing. The parameters setting in Experiment 1 is adapted from Lim and Haron (2013). Experiment 2 and 3 are the additional testing to test the performance of GA. In Experiment 2 and 3, the parameters which are number of gene and number of generation, are modified. This project intends to test whether the performance of GA will be affected by the parameters setting and how will it be affected. Table 3.2.2.3 shows the parameters setting for each experiment.

No.	**Parameter**	**Value**		
		Experiment 1	**Experiment 2**	**Experiment 3**
1.	Population Size	40	40	40
2.	Number of Genes	30	10	30
3.	Crossover Probability	0.7	0.7	0.7
4.	Mutation Probability	0.01	0.01	0.01
5.	Number of Generation	2000	2000	10000
6	Number of Testing	30	30	30

Table 3.2.2.3 Parameters Setting in Different Experiments

In this project, several tools, software and hardware are utilised to conduct the experiment. The details of tools are listed below, and the hardware specification is shown in Table 3.2.2.4 and the software specification is shown in Table 3.2.2.5.

Microsoft Visual Studio Community 2015

- Microsoft Visual Studio 2015 is an integrated development environment (IDE) from Microsoft, which is a commonly used tools to develop computer programs. Furthermore, Microsoft Visual Studio 2015 has many build-in libraries which provides support in developing the program in this project.

Notepad

- Notepad is a simple text editor for Microsoft Windows. The output produced from the program is saved using this program.

Microsoft Excel 2013

- Microsoft Excel is a spreadsheet developed by Microsoft for Windows, which performs calculation and tabling. Microsoft Excel 2013 provides support to the work of making statistics of the performance of GA models.

Hardware Specification

Hardware	**Description**
Processor	Intel® Core™ i5-5200U 2.20GHz
RAM	4.00 GB DDR3

Table 3.2.2.4 Hardware Specification

Software Specification

Software	**Description**
Operating System	Windows 8.1 64-bit
Development Tool	Microsoft Visual Studio Community 2015
Documentation Tool	Notepad Microsoft Excel 2013

Table 3.2.2.5 Software Specification

3.2.3 Implementation Phase

In the implementation phase, the coding of different operation techniques and benchmark functions is conducted successively. Furthermore, the coding is revised and the correctness of the coding is proved in this phase.

3.2.4 Testing Phase

After building a program which is able to perform all operation techniques and benchmark functions, the program is tested using white box testing technique. The coding of benchmark functions are tested by comparing the actual result with the expected result. Furthermore, each operation technique and the integration of operation techniques are also tested in this phase. After proving that the program is free from major defects, the experiment is conducted using this program to test the performance of the GA using the data which is randomly generated in the analysis phase. Thus, the performance of different GA towards the benchmark functions are determined by running the program and a good algorithm is found out by comparing the performances.

3.2.5 Documentation Phase

The output produced from the previous phase are documented in the documentation phase. In addition, the documentation includes the description of GA operation techniques, benchmark functions and parameters setting used in this project. Analysis on the result and comparison of GA models are conducted in this phase.

3.3 Implementation Issues and Challenges

The main challenge in this project is the coding of the algorithm has to be developed well, otherwise the overall performance of the algorithm will be affected. In addition, there are 72 combinations of operation techniques which are needed to be considered and experimented. Hence, this project consumes a lot of time in coding and testing phase.

Besides, the parameter settings is an important issue since it is the important factor of affecting the performance. The value of each parameter has to be ideal in order to get an optimal result.

3.4 Timeline

Analysis phase and design phase are the crucial phases in FYP 1. Literature review on GA and the exploration of algorithms in GA are needed to be performed in order to understand the background of this project. Furthermore, partial of coding is conducted in FYP1.

In FYP2, implementation phase, testing phase and documentation phase are the important phases. The coding is further improved and tested to test the GA models towards the benchmark functions. In addition, the result obtained from the experiments is saved and used to perform the analysis and discussion. The details of analysis and discussion are well documented in documentation phase.

3.4.1 FYP1 Gantt chart

Figure 3.4.1.1 shows the timeline of FYP1. FYP1 consists of analysis phase, design phase and part of implementation phase.

Task Name	Start	End	Duration (days)
Analysis	10/16/2017	10/29/2017	13
Study concept	10/16/2017	10/22/2017	6
Data collection	10/18/2017	10/24/2017	6
Previous works review	10/20/2017	10/26/2017	6
Define project objectives	10/28/2017	10/29/2017	1
Define project scope	10/28/2017	10/29/2017	1
Design	10/30/2017	11/6/2017	7
Identify tools and software	10/30/2017	10/31/2017	1
Explore algorithms	10/30/2017	11/1/2017	2
Define new constraints	11/2/2017	11/3/2017	1
Develop algorithms	11/2/2017	11/6/2017	4
Implementation	11/7/2017	11/27/2017	20
Conduct coding	11/7/2017	11/27/2017	20
Presentation preparation	11/25/2017	11/28/2017	3

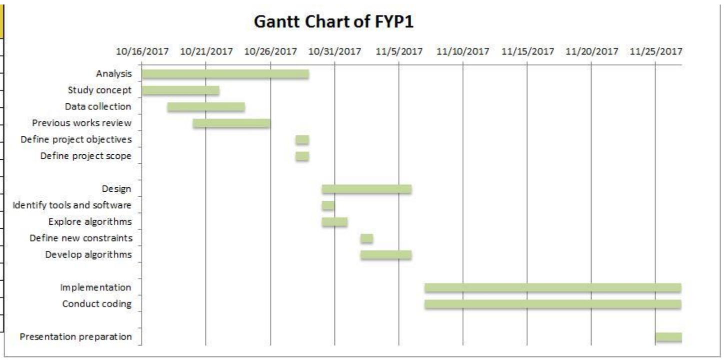


Figure 3.4.1.1 Gantt chart of FYP1

3.4.2 FYP2 Gantt chart

Figure 3.4.1.2 shows the timeline of FYP1. FYP2 consists of design phase, implementation phase, testing phase and documentation phase.

Task Name	Start	End	Duration (days)
Design	1/15/2018	1/20/2018	5
Define new constraints	1/15/2018	1/20/2018	5
Implementation	1/21/2018	2/21/2018	31
Conduct coding	1/21/2018	2/13/2018	23
Revise coding	2/14/2018	2/21/2018	7
Testing	2/22/2018	3/7/2018	13
Component Testing	2/22/2018	2/24/2018	2
Integration Testing	2/25/2018	2/26/2018	1
System Testing	2/27/2018	2/28/2018	1
Conduct Experiment	2/28/2018	3/7/2018	7
Documentation	1/22/2018	3/24/2018	61
Draft Report	1/22/2018	3/17/2018	54
Collect Experiment Result	2/28/2018	3/7/2018	7
Analyse Result	3/1/2018	3/17/2018	16
Poster Design	3/18/2018	3/20/2018	2
Finalise Report	3/21/2018	3/24/2018	3
Presentation preparation	3/25/2018	3/28/2018	3

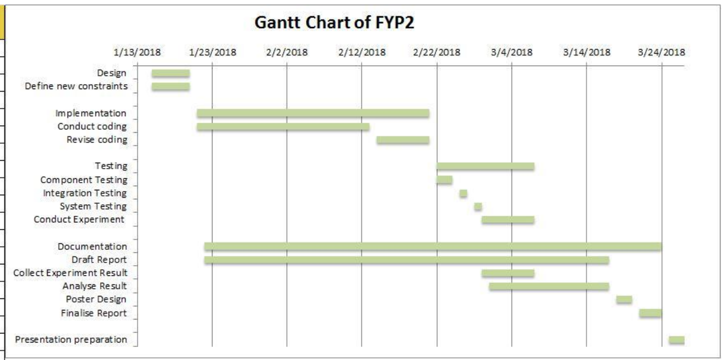


Figure 3.4.1.2 Gantt chart of FYP2

3.5 Summary

In this project, the program is written in C++ language using Microsoft Visual Studio Community 2015. Furthermore, this project is divided into 5 phases which are analysis phase, design phase, implementation phase, testing phase and documentation phase. By following the schedule of 5 phases, this project is able to be conducted and completed on time.

Chapter 4 Analysis and Discussion

4.1 Overview

Analysis and discussion are needed to identify the best combination of operation techniques in GA. The result from the executed program is collected and analysis is performed based on the result obtained. Hence, the analysis and discussion on the performance of GA models towards benchmark functions are included in this chapter.

4.2 Experimental Result

After the execution of code in the testing phase, the result of each GA model towards the benchmark functions is obtained. Average fitness value is the main criterion used to evaluate the performance of each GA model and the computation time is not considered in this project. This is because this project is focused on the optimisation towards the actual optimum for each benchmark function. Hence, the accuracy is more important than the speed of algorithm.

This section shows the result obtained from Experiment 1, Experiment 2 and Experiment 3. The result in Experiment 1, Experiment 2 and Experiment 3 which consists of minimum fitness value, average fitness value and average of time taken is shown in Appendix B. The following three simplified tables are focusing on the average of fitness value of the benchmark functions using 72 GA models in Experiment 1, Experiment 2 and Experiment 3.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average
GA01	20.56579	1074.469	0.001601	167134.3	91.34027	376.3562	182.4565	109.4404	293.4416	9.57013
GA02	9.332092	66.70759	0.000202	10450.94	4.867771	61.7298	3.927027	16.05448	16.08924	0.711319
GA03	20.77194	1808.857	0.130612	260268.2	126.2203	410.3113	389.3162	136.9287	437.6798	45.398
GA04	16.74632	273.5065	0.012275	41928.71	41.17384	225.0669	417.1895	76.31491	151.6045	6.123219
GA05	20.91307	1912.401	0.225468	304655.3	132.3706	448.4736	434.0371	156.2196	433.9321	65.39967
GA06	17.72367	540.9572	0.030367	77757.55	66.35145	245.3235	514.3538	97.01032	203.6059	17.99673
GA07	20.53603	936.9835	0.002084	145008.6	82.15864	381.0912	194.2652	107.506	281.0244	8.800633
GA08	9.052452	56.92097	0.000142	8704.112	4.103072	58.66084	4.015082	14.8975	15.59482	0.709229
GA09	20.91004	1457.885	0.108075	250615.6	105.3716	404.2283	377.3751	155.6076	355.9424	34.45146
GA10	15.37086	235.1428	0.009322	40666.7	35.11759	165.6508	388.6146	61.478	125.1517	6.026007
GA11	20.82019	1691.819	0.177004	263071.8	134.6518	438.2605	392.7839	150.6401	415.4092	52.92269
GA12	16.75421	303.9951	0.023203	54506.32	46.16188	194.7266	428.1974	83.07973	153.0889	11.41943
GA13	20.55493	945.6736	0.001966	144895	78.45007	378.4584	196.1169	111.2673	267.2903	7.102103
GA14	7.644545	35.83029	0.000162	6099.258	2.930884	47.14817	3.135518	11.91806	9.870449	0.513744
GA15	20.83939	1308.347	0.049292	210151.9	95.12488	400.0885	357.266	132.956	360.3166	23.91498
GA16	11.79191	115.8378	0.004846	19917.53	14.81981	81.21446	301.9741	35.58681	42.48865	3.052186
GA17	20.84837	1365.384	0.048508	202692.8	96.08921	393.5571	385.6614	142.7401	342.7494	30.14357
GA18	12.79316	127.5511	0.003946	25989.23	17.62037	102.7061	331.2637	44.87283	73.24546	4.298582
GA19	20.64919	3019.214	1.283593	480924.5	203.3372	468.1618	300139.5	301.6054	683.4823	165.8778
GA20	9.28224	74.26087	0.000278	11583.42	5.094102	65.33833	35.4329	18.03885	19.54745	0.879439
GA21	20.8772	3622.09	2.231398	568091.3	238.0418	544.0464	1850140	793.0001	838.5062	213.9156
GA22	16.8952	266.1507	0.003358	46641.92	36.25971	209.3305	231.415	64.47042	150.7057	5.92079
GA23	20.91133	3941.503	2.42019	673054.5	253.1406	536.06	1999982	805.8164	864.7193	248.8873
GA24	17.83175	458.8516	0.03942	85107.07	59.77894	224.3793	273.742	79.68543	205.4443	13.90807
GA25	20.5863	2965.413	1.197895	472027.3	196.519	478.0207	452919	366.9371	665.4558	149.4635
GA26	8.90803	58.91984	0.00034	9865.304	4.302551	60.73714	29.64483	15.96201	17.62789	0.795962
GA27	20.87731	3760.46	2.382266	615386.9	244.4179	543.235	2606685	828.5039	789.8362	211.7313
GA28	14.95463	226.8511	0.0069	34719.66	25.50328	143.3036	190.1382	54.16369	107.2684	4.88815
GA29	21.06149	3671.565	2.291933	619962.9	250.7347	537.53	2263701	821.8354	825.7177	226.7315
GA30	16.63186	319.9735	0.015575	58003.58	42.35453	197.0099	208.3011	75.35702	158.856	9.140717
GA31	20.51974	2773.522	1.119325	492006.7	205.7963	474.9812	421136.1	398.8238	681.9773	146.5188
GA32	7.716977	35.71634	0.000325	5831.371	3.012484	46.40077	23.48254	12.25099	10.3254	0.528012
GA33	20.90942	3842.184	2.395723	604813	258.8741	525.6108	2249354	900.8573	861.3359	193.7475
GA34	11.69069	115.0005	0.002832	19048.36	10.06556	73.89574	87.63406	33.01956	29.54316	2.170771
GA35	20.91251	3736.255	2.159591	546279.4	234.915	536.9339	2075234	824.2542	848.5047	216.2186
GA36	12.76414	105.6458	0.00387	18742.05	16.57445	95.83709	101.5685	40.26156	54.86337	3.275992
GA37	15.08736	309.1422	0.003142	53274.66	25.73689	135.6827	160.438	39.76763	84.45399	4.926796
GA38	8.02562	39.79164	0.000264	6298.647	3.02998	50.53154	17.73415	12.9394	11.607	0.607733
GA39	16.50095	737.706	0.054734	113798	48.20432	195.4126	316.8447	78.40713	173.5157	22.30716
GA40	18.29483	258.2206	0.008491	43866.49	60.58475	261.4353	266.2947	77.30205	183.8887	7.105126
GA41	18.62485	1219.211	0.140189	192150.7	82.70621	285.259	378.4361	127.8379	278.2881	42.23765
GA42	18.36487	484.9681	0.025032	81883.67	71.55678	271.2924	297.0268	102.9043	257.1312	17.72251
GA43	14.37316	323.1931	0.002885	50099.66	23.7963	129.5469	153.4214	42.51332	83.88874	5.121222
GA44	7.591199	35.60977	0.000438	5510.702	2.826074	46.3963	16.31143	11.76137	11.02533	0.602781
GA45	16.08295	571.8658	0.047369	89436.82	35.86455	173.4099	282.1704	71.14654	134.8776	19.86779
GA46	17.05243	236.7947	0.003777	34349.48	40.99176	199.2199	230.8265	66.84008	163.4162	5.803786
GA47	17.69941	988.1893	0.125389	144054.8	67.02442	233.9705	347.0059	116.9182	209.5676	23.4536
GA48	17.95905	302.8761	0.029125	56962.23	60.08005	247.7187	256.4615	90.77904	202.0682	12.35712
GA49	13.9679	265.1095	0.002547	45277.82	22.48095	115.2396	172.8708	35.73345	73.59115	4.096613
GA50	6.802356	26.90949	0.000204	3859.426	2.007728	39.23718	11.04303	10.6123	7.733123	0.460992
GA51	14.04173	406.7558	0.024919	72925.48	25.27112	130.4825	236.1068	52.56889	82.45192	13.21208
GA52	14.15473	138.3121	0.003621	22860.58	18.11937	121.3961	143.6713	43.96207	60.28178	3.757807
GA53	14.98137	424.5693	0.029616	71482.75	30.38804	148.191	246.5469	72.61123	105.3109	10.13756
GA54	15.48561	112.3463	0.003582	24260.45	29.93198	144.3179	149.1585	52.59243	101.0773	4.548254
GA55	9.072523	57.4312	0.000582	9544.471	4.806545	64.72252	26.90369	17.32832	17.27362	0.798674
GA56	6.265136	21.04718	0.000165	3661.992	1.462227	39.26655	8.546602	10.1881	6.405044	0.520216
GA57	15.98922	506.3466	0.029509	78790.13	43.3144	150.338	317.8449	71.42135	145.5856	22.5792
GA58	18.90346	285.0272	0.006965	40971.48	82.05877	276.786	305.7025	85.70653	254.5194	9.332706
GA59	18.73026	1171.115	0.143484	214152.4	85.89141	274.4067	363.4678	109.4024	289.3996	49.82969
GA60	19.01916	652.0072	0.041789	117354.7	90.6008	316.3794	337.208	111.1539	337.0832	25.00922
GA61	8.760882	53.59625	0.000767	8794.303	4.387399	64.79814	26.06367	16.14659	17.93103	0.789692
GA62	6.507959	19.03706	0.000223	3220.589	1.390228	37.55343	7.526811	9.553056	6.036686	0.483311
GA63	14.75633	396.5758	0.048881	83173.93	41.47852	125.9325	283.8206	55.35444	108.7168	20.94118
GA64	18.49583	230.0261	0.011301	42741.16	60.82267	262.2478	292.9008	85.0314	201.8441	7.603536
GA65	17.85241	888.3606	0.067665	131910.2	68.61324	233.0047	332.0727	102.7003	220.6193	25.62259
GA66	18.26977	357.3589	0.029881	63580.94	71.22137	271.783	297.1203	98.63827	263.5087	18.35322
GA67	8.280354	48.96557	0.000456	8285.959	3.859468	57.45879	20.24106	15.39482	15.37717	0.649219
GA68	5.974494	18.01044	0.000257	2681.914	1.251684	33.32803	7.239084	8.572312	5.569779	0.426452
GA69	12.93076	365.7294	0.010692	51894.32	17.44547	88.23275	261.1628	43.82712	55.72906	9.464214
GA70	16.34857	164.0408	0.007123	25014.45	29.57628	184.4279	164.08	56.16895	120.7972	5.234945
GA71	14.51827	311.631	0.014435	56250.5	27.63138	125.4477	205.3067	58.39606	81.69823	9.930666
GA72	16.75466	156.0514	0.006522	28833.92	41.52131	196.1082	197.3182	63.66372	148.1801	7.989935

Table 4.2.1 Average Fitness Value of Benchmark Functions in Experiment 1

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average
GA1	19.41683	6.735059	0.000893	1527.853	1.360267	43.35376	8.404461	10.36517	6.647599	0.129242
GA2	4.042195	0.527132	0.000248	91.04441	0.101246	6.122096	0.25253	1.462566	1.44217	0.090634
GA3	20.04035	22.29345	0.014302	4496.797	4.025176	45.66154	43.53022	17.10868	20.18018	0.261221
GA4	10.80785	3.917197	0.004919	988.3523	3.068235	21.27912	56.5118	12.02667	12.24327	0.251783
GA5	19.84614	32.25265	0.02643	6272.096	9.077119	62.97061	52.75644	22.72199	24.96073	0.59919
GA6	12.4412	8.411304	0.003355	731.2047	5.618545	35.65779	54.5248	17.22255	18.52311	0.368892
GA7	19.97915	9.643004	0.000578	1189.854	1.600891	34.53307	7.053596	7.991875	6.112857	0.108348
GA8	3.875561	0.458309	6.62E-05	90.00483	0.106412	6.09825	0.301802	1.303678	1.313074	0.077985
GA9	19.60288	16.40681	0.00844	3431.309	2.933586	38.60225	33.36072	14.50662	10.93505	0.273638
GA10	8.565813	7.055694	0.002144	900.7702	2.258835	17.91051	45.85501	7.838036	6.533951	0.245391
GA11	19.9407	28.62459	0.009568	5411.242	5.884052	54.9153	49.64624	18.19491	16.69977	0.453808
GA12	9.984036	6.833124	0.001353	1057.773	4.684229	29.32819	44.02761	13.94413	16.46341	0.290065
GA13	19.528	7.97821	0.001391	1092.055	1.373605	36.75832	4.965923	7.568507	5.556222	0.108979
GA14	3.393532	0.512871	0.000209	77.86321	0.08909	5.083034	0.340638	1.346836	1.312613	0.055585
GA15	19.45137	15.73851	0.011918	2201.005	2.213578	32.38371	33.08904	11.00332	10.03127	0.38236
GA16	6.714453	4.681763	0.001521	463.6458	1.298838	10.81417	29.27522	6.632166	4.630128	0.176441
GA17	19.94443	19.87207	0.008275	3344.556	2.5181	44.04491	46.09797	13.11632	16.2061	0.245835
GA18	7.959719	2.903726	0.001226	660.7909	2.538301	20.29869	35.57802	9.47551	11.7102	0.183928
GA19	20.11336	286.4062	0.67924	48823.58	53.53187	134.5138	2104.383	106.6826	168.7575	11.02324
GA20	4.136121	0.723362	0.000157	96.75978	0.121428	5.734661	0.645528	1.653758	1.557631	0.06434
GA21	20.10658	388.6211	1.094369	63909.38	69.80731	168.2898	25230.71	206.8303	238.3269	26.00168
GA22	10.85263	5.688367	0.001576	831.416	1.814757	19.31421	16.25624	9.900344	7.977171	0.236242
GA23	20.47285	392.1718	1.4215	65368.13	67.11856	183.5443	23960.9	209.3157	232.445	24.68907
GA24	11.84733	4.609755	0.001042	908.0094	2.735523	30.64006	29.04338	13.67967	14.02745	0.24902
GA25	20.17316	299.4679	0.555354	44081.9	50.49836	141.3639	5884.68	113.7056	162.8292	12.35959
GA26	3.781605	0.473522	0.000153	115.8086	0.112725	5.494948	0.433858	1.458024	1.409983	0.052641
GA27	20.43796	407.5363	1.068728	64290.14	69.71065	170.6623	38702.9	266.8832	258.4727	17.04934
GA28	8.601218	5.878306	0.00087	523.1921	1.870323	12.81099	14.19333	6.167041	4.643344	0.122275
GA29	20.51506	437.4024	1.345163	71656	78.19765	167.6603	53101.54	293.3528	265.3411	20.42344
GA30	9.809136	4.931961	0.001841	535.589	2.407744	23.73758	18.52444	11.2511	10.51886	0.143242
GA31	20.25767	244.6825	0.517686	43901.13	48.39862	137.6072	1710.39	122.7541	179.8467	12.75273
GA32	3.496674	0.484795	0.000264	100.4696	0.101619	5.642519	0.512855	1.375361	1.304901	0.046459
GA33	20.3326	345.3481	1.033156	60003.04	62.1482	163.6203	24941.79	259.1206	209.9964	17.87054
GA34	6.926094	3.196134	0.000772	280.3266	0.992809	11.41022	4.961813	5.076794	2.876842	0.091119
GA35	20.58675	380.4579	1.172235	59119.68	59.40685	161.9944	28962.03	205.9343	274.0716	22.72435
GA36	7.808327	3.25689	0.000781	373.4523	1.381426	15.93793	7.59328	7.106321	5.992951	0.134476
GA37	6.805283	3.298342	0.001149	493.1312	0.839585	13.89704	3.67079	3.893943	3.483561	0.155572
GA38	3.797515	0.451331	0.000353	99.95718	0.102804	5.863349	0.426221	1.426127	1.328676	0.070184
GA39	6.097305	19.30161	0.009228	3085.67	1.906013	15.84333	35.79757	6.994827	5.250801	0.420296
GA40	11.83989	6.966803	0.002202	492.3022	4.039229	29.78622	26.32568	14.28963	14.21373	0.270406
GA41	10.63323	20.87431	0.015205	3576.921	4.060469	27.83421	49.92701	14.87755	12.7243	0.57689
GA42	13.59995	4.79666	0.002894	720.5978	5.722652	39.63841	31.22766	14.92375	22.31336	0.480033
GA43	6.800013	2.572284	0.001142	450.7906	0.62347	13.90882	4.312649	3.602939	2.781223	0.179011
GA44	3.536297	0.452525	0.000263	73.02403	0.084879	5.169173	0.368621	1.560535	1.300625	0.070768
GA45	5.809658	15.38357	0.010657	2419.482	1.201733	8.569575	24.33164	6.201483	3.467057	0.379832
GA46	9.978216	3.638124	0.001782	926.8241	3.748544	24.25096	20.02738	11.70438	11.34862	0.228709
GA47	8.872074	13.53963	0.005959	3215.12	1.98588	20.51633	34.36931	9.368313	7.46715	0.36091
GA48	12.32599	4.278034	0.003113	1155.76	3.742171	30.14357	23.61916	11.70626	14.766	0.231952
GA49	6.443754	2.815111	0.001455	412.0864	0.537677	13.09662	3.87518	3.838614	3.053594	0.159158
GA50	3.59916	0.478141	0.000285	63.62138	0.073945	5.548015	0.315422	1.262258	1.302995	0.052289
GA51	5.413203	11.55173	0.005164	1650.095	0.539417	10.18794	17.50203	5.200415	2.306396	0.218465
GA52	8.843039	3.67563	0.000498	697.084	1.371492	19.5509	13.74146	7.620914	8.23791	0.111504
GA53	6.714585	17.18458	0.003131	2079.499	1.198013	13.48613	31.98231	8.568115	5.311824	0.358458
GA54	10.61644	2.672604	0.000326	551.3914	1.952669	24.4945	13.68741	8.628045	10.48212	0.138558
GA55	4.146467	0.925418	0.000811	117.1208	0.161438	7.330608	0.597199	1.608089	1.500242	0.131035
GA56	3.339108	0.507669	0.000109	68.04538	0.068126	5.034815	0.25264	1.33907	1.327594	0.082042
GA57	5.50592	24.36649	0.009645	4016.047	1.010685	14.77309	24.01174	6.243999	4.049861	0.322064
GA58	14.22094	6.273131	0.002493	1211.748	7.341919	43.48497	37.9376	15.88969	21.83613	0.288589
GA59	9.513875	22.93878	0.017977	4407.611	2.389305	26.04162	51.0885	12.7298	12.42013	0.647206
GA60	14.41145	7.124779	0.001127	1033.698	10.09764	49.99488	42.44058	21.66266	31.37928	0.424894
GA61	3.908414	0.602237	0.000453	103.9583	0.144193	7.225313	0.684126	1.718143	1.373793	0.109244
GA62	3.336603	0.394383	0.000287	64.74215	0.076308	5.066609	0.309151	1.344727	1.29172	0.061519
GA63	5.266157	18.13829	0.013537	3353.966	0.982213	8.989075	23.57082	6.749706	2.904985	0.34779
GA64	13.47997	6.038943	0.002628	1138.056	4.568389	37.5537	27.45454	13.01546	15.1404	0.337391
GA65	7.799312	21.17577	0.014174	3372.705	1.276634	16.71118	37.85332	11.07696	5.921335	0.428061
GA66	12.87035	9.793996	0.003912	1128.984	5.582952	36.94539	32.07775	17.01023	23.18286	0.358929
GA67	4.179323	0.882374	0.000503	134.458	0.105929	7.091169	0.555144	1.696132	1.622371	0.088768
GA68	3.383597	0.310029	0.000144	58.98513	0.064881	5.332972	0.311001	1.199983	1.248965	0.065461
GA69	4.565009	11.54578	0.005489	2304.957	0.400171	8.25748	12.41252	3.790051	3.03445	0.265152
GA70	11.41921	4.434642	0.001925	686.827	2.481991	25.66079	20.77573	9.3268	12.92933	0.128461
GA71	5.961598	17.07294	0.003773	1788.459	1.18121	10.77579	22.2239	5.394345	3.658639	0.281141
GA72	11.73988	6.249701	0.001017	963.2771	4.706573	32.25208	27.23729	11.9999	17.98651	0.20069

Table 4.2.2 Average Fitness Value of Benchmark Functions in Experiment 2

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average
GA01	20.57623	760.5721	0.0000709	113616.4	72.5651	374.4992	115.2411	97.6003	263.2606	0.983559
GA02	2.539596	1.232133	9.33333E-06	183.2553	0.085427	7.369027	0.120554	2.080566	1.333472	0.163313
GA03	20.63428	538.21	0.006138833	72658.45	36.3963	274.9779	278.0256	79.88156	128.0457	9.650331
GA04	16.49499	33.21433	0.001335133	5790.35	28.66717	158.7239	360.8128	53.77057	88.05529	1.539087
GA05	20.97133	1263.912	0.069076467	210622.1	82.51344	376.4963	401.7363	133.0013	321.4896	22.63171
GA06	17.88529	48.28721	0.002886867	7238.818	65.47181	228.0398	432.8141	93.95443	206.4161	4.401229
GA07	20.61299	709.736	0.0000244	91711.89	65.61478	373.547	135.8321	96.23106	223.8507	0.964285
GA08	2.42464	1.009734	1.18667E-05	182.8552	0.082044	7.399081	0.118897	1.863523	1.279091	0.144138
GA09	20.66372	577.7321	0.008421133	68970.25	38.20233	271.2959	310.8833	84.43629	116.4733	5.641025
GA10	14.45417	40.50362	0.0015324	4800.106	15.67875	116.334	345.2711	38.91252	57.25304	1.778141
GA11	20.88009	907.8505	0.0394331	146556.1	65.89359	333.2015	370.5564	118.8467	223.5303	17.36417
GA12	16.44432	35.95375	0.005147833	7295.514	46.36995	188.7254	367.7855	80.69998	134.6886	3.315901
GA13	20.59204	530.0488	4.91333E-05	75738.17	57.71997	359.3126	122.8457	95.51115	175.9179	0.696866
GA14	2.240608	0.774058	1.11333E-05	148.4613	0.053048	6.278977	0.102926	1.661443	1.205699	0.117771
GA15	20.70422	476.864	0.005280633	68013.77	23.24135	242.6016	259.4716	76.54412	99.25631	3.143034
GA16	11.43297	20.33992	0.000637133	3788.803	5.380547	64.76167	275.9295	23.14155	33.2785	0.816859
GA17	20.74631	584.5252	0.0116476	71911.03	43.80441	273.55	280.975	74.83472	135.2243	3.911438
GA18	13.03216	17.01911	0.000786133	2839.299	18.23875	100.2099	289.8937	44.57949	57.83759	1.543167
GA19	20.70558	3056.911	1.240557667	482235.4	190.2178	477.9649	303799.7	385.7294	672.4492	164.185
GA20	2.524152	1.207527	0.0000119	207.6938	0.090521	8.815296	0.450706	2.155579	1.314129	0.164814
GA21	20.8511	3815.043	2.2388409	612247.9	225.045	544.9426	2791685	802.5802	749.2643	228.0006
GA22	16.89511	33.80249	0.000482767	6050.827	24.75718	160.0424	189.62	43.33729	68.08026	1.4928
GA23	20.99926	3983.853	2.547228967	665930.6	237.9201	562.0001	2942611	746.2242	910.7332	228.5561
GA24	17.66011	53.08255	0.0027847	5974.886	52.51387	228.5387	277.2035	90.46082	173.357	5.000962
GA25	20.60369	2937.702	1.1265345	493644.7	203.6492	463.3276	341907.6	397.0653	680.8553	153.8403
GA26	2.5589	1.205183	1.07333E-05	168.3024	0.094304	7.706955	0.390725	1.893474	1.274117	0.153841
GA27	20.65944	4006.163	1.8767502	608362.5	242.7027	542.0944	3079336	1050.037	888.3989	240.5329
GA28	15.33101	40.41462	0.0010893	5526.603	13.89969	124.741	152.8415	36.80876	35.02586	1.811515
GA29	20.93775	3852.225	2.434053433	603492.8	257.5388	539.9494	4322946	851.0936	888.7063	227.696
GA30	16.46652	38.15137	0.001989433	6483.366	40.25102	179.9585	190.2894	74.61645	125.6971	3.568936
GA31	20.66265	3007.873	1.160180167	438652.2	197.0599	460.6875	285711.9	350.6888	677.7256	153.2803
GA32	2.212986	0.875899	0.0000089	144.7205	0.05757	6.429043	0.285273	1.742512	1.192637	0.112076
GA33	20.81641	3712.994	2.138823967	668625.4	231.4265	529.5639	5115475	753.2847	840.6834	188.1779
GA34	10.43999	14.33557	0.000413933	2384.859	2.895337	55.58287	57.23797	20.15596	21.62262	1.050645
GA35	20.91417	3753.252	2.542408067	644218.9	248.8788	528.1771	4583894	919.0624	889.251	222.8458
GA36	13.22579	12.38674	0.000624	3270.697	12.42152	90.72563	98.09322	35.98096	48.44418	1.107176
GA37	13.59991	221.1957	0.0002611	41596.1	20.22413	104.6183	126.4278	29.50288	73.19002	3.331599
GA38	2.096144	0.832812	9.43333E-06	149.7131	0.060291	6.0057	0.238757	1.747382	1.20989	0.137487
GA39	4.84425	117.9876	0.0038331	16861	0.83686	21.13089	101.7077	8.583105	5.005743	4.204132
GA40	17.49941	33.6872	0.0008877	5871.879	36.66139	218.8039	274.207	55.79849	128.9869	1.563341
GA41	13.52667	237.1268	0.018780067	40428.72	26.83185	124.3984	255.802	54.15635	77.30909	6.117476
GA42	18.42081	37.50872	0.0020443	8070.019	64.4998	264.63	285.0701	91.82955	261.2053	4.784682
GA43	13.70065	229.4966	0.000376667	37586.71	19.0684	101.8589	135.2853	27.4314	63.85039	3.45841
GA44	2.116527	0.722475	1.36333E-05	123.3689	0.049679	6.416897	0.2173	1.671005	1.175109	0.11524
GA45	3.998794	110.5274	0.0177712	21550.67	0.464959	16.45736	90.25562	7.929252	3.537073	2.64575
GA46	17.60568	36.78379	0.000533667	7556.468	28.93012	206.9524	197.8911	50.69048	103.6021	1.860801
GA47	12.07667	123.1215	0.007209467	27549.37	12.41707	85.96641	201.7288	45.16177	45.24109	4.470286
GA48	17.53309	58.07449	0.001521767	8247.881	58.57431	238.1593	232.9752	85.73633	182.6266	4.009728
GA49	13.00083	187.1704	0.0002748	32714.03	16.12996	86.19018	161.794	22.53816	53.73139	3.076174
GA50	2.096886	0.601441	0.0000164	104.5816	0.046259	6.196749	0.203682	1.558705	1.166559	0.114846
GA51	3.126031	56.90241	0.002649233	10599.3	0.293538	10.96114	54.77436	3.837181	2.244423	1.848426
GA52	14.35532	17.03383	0.000369233	4027.655	13.94199	105.9806	106.7317	32.14429	41.12558	1.392799
GA53	6.705095	59.40603	0.0080029	11340.65	2.562635	38.04823	88.84069	18.5413	7.875423	1.336028
GA54	15.53951	24.25453	0.001461433	4492.911	26.0522	148.04	139.5444	50.53625	84.05231	1.515117
GA55	4.019771	4.535244	1.30333E-05	784.1736	0.377934	17.96789	1.697502	4.394306	2.746101	0.420989
GA56	1.967323	0.608642	2.09333E-05	106.8429	0.041242	6.11367	0.163391	1.588668	1.130553	0.117971
GA57	4.472116	188.1447	0.003688267	31957.07	0.708162	19.21592	107.7443	4.305237	4.202003	3.986112
GA58	18.70611	39.12285	0.0006215	6855.677	57.75361	274.3192	279.986	77.87779	168.8285	1.473222
GA59	12.94475	311.1738	0.006862133	51376.72	16.10072	101.6759	223.9068	41.22924	74.30651	7.628978
GA60	18.89726	60.88543	0.001716133	8591.632	89.79034	289.2131	340.3696	98.92564	288.5292	4.712396
GA61	3.862441	4.263035	2.45333E-05	948.2379	0.321736	18.70107	1.54295	4.406487	2.347353	0.462608
GA62	1.842767	0.61154	1.11667E-05	97.92696	0.035771	5.23145	0.151975	1.455386	1.136368	0.115157
GA63	3.068374	150.6593	0.0048232	20901.88	0.911587	28.42478	83.89201	8.526638	4.310643	3.715619
GA64	18.30661	41.38	0.004399567	7649.708	35.19216	249.3924	252.3221	67.79051	170.6875	1.761543
GA65	11.3985	139.7848	0.0094978	24187.48	9.937687	80.52429	191.6334	37.30589	30.31809	4.930465
GA66	18.25023	54.62162	0.002493267	6885.642	74.43189	258.7963	285.2151	99.88508	234.9207	5.000658
GA67	4.029129	4.314657	2.89667E-05	640.6739	0.348092	16.62354	1.733546	3.671853	2.207446	0.379794
GA68	1.791814	0.504085	1.07333E-05	99.72666	0.034187	4.527581	0.126124	1.383581	1.126049	0.122913
GA69	3.303041	71.89099	0.0015727	13026.35	1.187891	15.08512	59.39101	9.28876	2.27172	1.83497
GA70	15.26634	28.0236	0.0008993	4747.969	21.78982	148.4557	155.483	41.35637	77.31618	1.926293
GA71	6.132664	42.69297	0.003269967	11109.93	1.384182	31.87908	100.719	15.83073	5.675238	1.390461
GA72	16.6136	30.40343	0.0008239	4893.73	36.87297	180.1602	204.7304	63.4605	118.7648	2.837003

Table 4.2.3 Average Fitness Value of Benchmark Functions in Experiment 3

In the tables, B1 is referred as Benchmark Function 1 in Section 2.10 and GA01 is referred as GA model 1 in Table 3.2.2.2. The applied operation techniques in each GA model is derived from the table in Appendix A and the respective parameters setting of each experiment is mentioned in Section 3.2.2.

In next section, only the top 10 GA models for each benchmark function in each experiment are discussed. The top 10 GA models as stated in this project is determined and evaluated using the average values as shown in Table 4.2.1 to Table 4.2.3. There are the lowest and minimum compared to the others GA models. This proves that their performance is greater than the others 62 GA models in each benchmark function.

In the following tables, occurrence shows the total of existence for a particular GA model appeared in the top 10 GA models of benchmark functions. However, the more occurrence of a particular GA model does not determine its performance is better than the others. For example, a GA model appears 9 times in the top 10 list but all of them occupy the lower ranking of GA models and another GA model appears only 5 times but all of them occupy the upper ranking of GA models. Hence, the performance of GA models is calculated using weighting and rating method, suggested by James. In order to distinguish the importance of each rank, different weighting is assigned respectively. Even though this method is subjective and personal bias, it is effective to gain a quantitative answer.

The weight is assigned in the range from 0 to 1. Top 1 is the best among all the ranking. Hence, it should be assigned with the highest weight, which is 1.0. For Top 2, it is higher compared to the other ranking, but it is lower compared to Top 1. Therefore, it is assigned with 0.9, which is slightly lower than the weight of Top 1. The remaining ranking are assigned according to this criteria. As for Top 10, it is the weakest among the ranking. However, it is still able to achieve in Top 10 compared to the remaining 62 GA models, so it is assigned with 0.1 instead of 0.0. Table 4.2.4 shows the weight of each ranking.

Ranking	**Top 1**	**Top 2**	**Top 3**	**Top 4**	**Top 5**	**Top 6**	**Top 7**	**Top 8**	**Top 9**	**Top 10**
Weight	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1

Table 4.2.4 Weight of Ranking

The performance calculation is as derived using the formula as stated below. The higher the percentage of the performance, the better the GA model in solving the optimisation problem.

$$Performance\ of\ GA\ model, f(x) = \frac{\sum_{i=1}^{10} x_{top\ i} \times weight_{top\ i}}{total\ occurrence\ of\ GA\ model} \times 100\% \quad (1)$$

Where,

x is the occurrence of GA model

$top\ i$ is the ranking of GA model

total occurrence of GA model = 10

4.3 Analysis and Discussion for Experiment 1

This section includes the analysis and discussion for Experiment 1. Based on the result of Experiment 1 shown in Table 4.2.1, top 10 GA models for each benchmark functions are identified. Table 4.3.1 shows the 10 best GA models in solving each benchmark function. Table 4.3.2 shows the occurrence and performance of GA models in Experiment 1. The calculation for Performance (%) is derived using Formula (1). Table 4.3.3 shows the operation techniques on top 10 GA models.

Benchmark Functions	**GA Models Ranking in Experiment 1**									
	Top 1	**Top 2**	**Top 3**	**Top 4**	**Top 5**	**Top 6**	**Top 7**	**Top 8**	**Top 9**	**Top 10**
B1	GA68	GA56	GA62	GA50	GA44	GA14	GA32	GA38	GA67	GA61
B2	GA68	GA62	GA56	GA50	GA44	GA32	GA14	GA38	GA67	GA61
B3	GA08	GA14	GA56	GA02	GA50	GA62	GA68	GA38	GA20	GA32
B4	GA68	GA62	GA56	GA50	GA44	GA32	GA14	GA38	GA67	GA08
B5	GA68	GA62	GA56	GA50	GA44	GA14	GA32	GA38	GA67	GA08
B6	GA68	GA62	GA50	GA56	GA44	GA32	GA14	GA38	GA67	GA08
B7	GA14	GA02	GA08	GA68	GA62	GA56	GA50	GA44	GA38	GA67
B8	GA68	GA62	GA56	GA50	GA44	GA14	GA32	GA38	GA08	GA67
B9	GA68	GA62	GA56	GA50	GA14	GA32	GA44	GA38	GA67	GA08
B10	GA68	GA50	GA62	GA14	GA56	GA32	GA44	GA38	GA67	GA08

Table 4.3.1 Top 10 GA Models in Experiment 1

GA Model	**Ranking in Experiment 1**										**Occurrence**	**Performance (%)**
	Top 1	**Top 2**	**Top 3**	**Top 4**	**Top 5**	**Top 6**	**Top 7**	**Top 8**	**Top 9**	**Top 10**		
GA20	0	0	0	0	0	0	0	0	1	0	1	2
GA61	0	0	0	0	0	0	0	0	0	2	2	2
GA02	0	1	0	1	0	0	0	0	0	0	2	16
GA67	0	0	0	0	0	0	0	0	7	2	9	16
GA08	1	0	1	0	0	0	0	0	1	5	8	25
GA38	0	0	0	0	0	0	0	9	1	0	10	29
GA32	0	0	0	0	0	5	3	0	0	1	9	38
GA44	0	0	0	0	6	0	2	1	0	0	9	47
GA14	1	1	0	1	1	3	3	0	0	0	10	59
GA50	0	1	1	6	1	0	1	0	0	0	10	69
GA56	0	1	6	1	1	1	0	0	0	0	10	75
GA62	0	6	2	0	1	1	0	0	0	0	10	81
GA68	8	0	0	1	0	0	1	0	0	0	10	91

Table 4.3.2 Occurrence and Performance of GA Models in Experiment 1

	Selection				Crossover			Mutation			Replacement	
GA model	Roulette Wheel	Random	Rank	Tournament	Single Point	Two Point	Uniform	Flipping	Interchanging	Reversing	Random	Weak Parent
GA20		✔			✔			✔				✔
GA61				✔		✔		✔			✔	
GA02	✔				✔			✔				✔
GA67				✔			✔	✔			✔	
GA08	✔					✔		✔				✔
GA38			✔		✔			✔				✔
GA32		✔					✔	✔				✔
GA44			✔			✔		✔				✔
GA14	✔						✔	✔				✔
GA50			✔				✔	✔				✔
GA56				✔	✔			✔				✔
GA62				✔		✔		✔				✔
GA68				✔			✔	✔				✔

Table 4.3.3 Operation Techniques of Top 10 GA Models in Experiment 1

Based on Table 4.3.1, GA68, GA56, GA62, GA14, GA38, and GA50 have occurred 10 times followed by GA44, GA32, and GA67 with 9 occurrence which represents these GA models have good performance in solving every benchmark function. Among the GA models that have occurred 10 times, GA68 has been the Top 1 GA model for 8 out of 10 benchmark functions, GA62 has been the Top 2 GA model for 6 out of 10 benchmark functions and GA56 has been the Top 3 GA model for 6 out of 10 benchmark functions. Hence, GA58, GA56 and GA62 are the top 3 best GA models in Experiment 1.

4.3.1 Selection Operation Technique Perspectives

Among those GA models, 5 of them are Tournament Selection, 3 of them are Rank Selection, 3 of them are Roulette Wheel Selection, and 2 of them are Random Selection. As mentioned above, GA68, GA56, and GA62 are the top 3 GA models in Experiment 1. Based on Table 4.3.3, the selection operation technique of these three GA models is Tournament Selection. This shows that Tournament Selection has the best performance compared to other selection operation techniques. The second best selection operation technique is Rank Selection. Roulette Wheel Selection is the third. Last, Random Selection has the worst performance among these four selection operation techniques. However, the difference of occurrence of each selection operation technique is not much. This shows that technique used in selection operation is not the main factor that affecting the performance of a GA model.

Tournament Selection and Rank Selection are similar. They randomly choose a number of individual to be involved into a competition and then, the higher fitness value individual is chosen as the parent. The difference between them is the size of the competition. In Rank Selection, there are only two individuals are selected for the fitness value comparison. On the other hand, Tournament Selection usually select more than two individuals for the competition pool, two-thirds of the population is selected into the competition pool in this project. The more the individuals included in the competition pool, the higher the chances of selecting a high fitness value individual as the parent. However, using Tournament Selection, it has a higher chance to select same individual as the parent in different generations. This reduces the chances of selecting the other individuals as it has a good gene but not high fitness value and produces similar individuals in the population which results the stuck in local optimum. On the other side, Rank Selection is able to prevent the quick convergence as the ability to select different individual as the parent.

In Roulette Wheel Selection, every individual occupies different area of slice in the roulette wheel based on its fitness value and the area of slice represents its probability to be selected as a parent. If the fitness value of an individual is higher, the slice given to this individual will be larger. In this technique, every single individual stands a chance to be selected and this may introduce the weaker individual as the parent. However, the limitation of this technique is if an individual has a big lead of fitness value than others, then the weaker individuals will have very small area of slices. This causes the weaker individuals have very less chances for being selected. Last, Random Selection is the worst technique among these four selection operation techniques. Random Selection selects an individual as the parent without considering its fitness value. The advantage of this technique is every individual has the equal chance to be selected. Hence, it is able to introduce a weaker individual which might contains a good gene as the parent and increase the population diversity. However, Random Selection slows down the evolution of the population and not able to obtain an optimum result when weak children is produced in each generation.

The best selection operation technique is Tournament Selection and the other selection operation techniques also have a good performance in solving different optimisation problems.

4.3.2 Crossover Operation Technique Perspectives

Based on Table 4.3.2, all of the crossover operation techniques have appeared for similar number of occurrence. This shows that crossover has less effect to the performance of GA models compared to other operation techniques. However, there is a pattern of the occurrence of crossover operation techniques. Uniform crossover always performs better than other two crossover operation techniques when the GA models contains exactly the same operation techniques. The second best is the Two Point Crossover and the last is Single Point Crossover.

The purpose of crossover is to produce a stronger child by copying the good genes from its parent. Single Point Crossover separates the genes of the individual into two parts and exchanges one part with the part from another individual. The advantages of this technique are the children are less diverse and similar to their parents. When the population has evolved enough generation, good fitness value individuals are produced in the population. Single Point Crossover is good at this situation because it is able to keep the good genes for the children while performing the crossover. On the other hand, Single Point Crossover needs more iterations to produce a good individual since it provides low diversity of population. Two Point Crossover is similar to Single Point Crossover, it has one more crossover point. This makes the children is more diverse and able to produce a good individual at a faster pace than Single Point Crossover.

Uniform Crossover is proved as the best crossover operation technique based on the result of Experiment 1. Uniform Crossover generates a binary crossover mask to determine which genes it should copy from the respective parent. Uniform Crossover produces a more diverse and very different children from the parents. The advantages of this technique are a stronger individual is introduced faster compared to the other two crossover operation techniques and the diversity of population increases. Hence, the best fitness value individual is not able to remain as the best for too long unless it reaches the optimum value. As mentioned above, in the later generation, good genes are desired to be kept inside an individual. Uniform Crossover could separate the good genes into two children and children with lower fitness value are produced.

Crossover operation is not the major factor of affecting the performance of GA models. Based on the analysis, Uniform Crossover is the best crossover operation technique followed by Two Point Crossover and Single Point Crossover.

4.3.3 Mutation Operation Technique Perspectives

From Table 4.3.3, it shows that top 10 GA models for every benchmark functions are using Flipping Mutation. Interchanging and Reversing are totally not included in the top 10 GA models.

Mutation operation alters the value of the genes to prevent the GA to be trapped in the local optimum. Flipping Mutation changes the value of the genes from the initial value into a new randomly generated value. This might make the individual to have a better fitness value. The disadvantage of this technique is if the new value is worse than the initial value, then a worse fitness value individual is produced.

Interchanging Mutation and Reversing Mutation do not generate a new value to replace the initial value but swapping the position of the genes. In Interchanging Mutation, the value of two genes is swapping to the position of each other. In Reversing Mutation, the value of a gene and next to it is reversing ascending order or descending order. These two mutation operation techniques do not make any difference in the value of genes. The effect of these two mutation techniques happens while performing crossover in next iteration. For example, if all the individual of a population are similar, a different child will be produced by swapping the value of genes. The limitation of these two mutation operation techniques is not able to escape from the local minimum when the genes of the best individual are similar.

Based on the result, mutation operation is the major factor of affecting the performance of GA models towards the benchmark functions. Flipping has a better performance compared to Reversing and Interchanging.

4.3.4 Replacement Operation Technique Perspectives

Most of the top 10 GA models are using Weak Parent Replacement. Hence, it proves that Weak Parent Replacement is better than Random Replacement. The main reason is Weak Parent Replacement always replaces the weaker parents with the stronger children and Random Replacement randomly selects an individual to be replaced. In this case, Weak Parent Replacement is able to keep good individuals in the population. On the other hand, Random Replacement might replace a good individual with a worse child and this prevents the GA model from getting more optimal result. In addition, a better individual does not always have the best genes. Sometimes, the worse individual might have a better gene compared to a better individual but the other worse genes inside that individual cause its low fitness value. So, the worse individual with the best gene will be replaced. This situation can be potentially avoided using Random Replacement since it performs the replacement randomly but not based on the fitness value. However, this is not effective since the worse individual with the best gene still stands a chance to be replaced using Random Replacement.

Based on the result, replacement operation is one of the major factors of affecting the performance of GA models towards the benchmark functions. Weak Parent Replacement always performs better than Random Replacement.

4.3.5 Findings on Experiment 1

Based on the result from Experiment 1, Tournament Selection, Uniform Crossover, Flipping Mutation and Weak Parent Replacement is the best combination of operation techniques. These operation techniques are included in GA68 and it works well in most of the benchmark functions.

4.4 Analysis and Discussion for Experiment 2

This section includes the analysis and discussion for Experiment 2. The changes parameters setting in Experiment 2 is stated in Table 3.2.2.3. Based on the result of Experiment 2 shown in Table 4.2.2, top 10 GA models for each benchmark functions are identified. Table 4.4.1 shows the 10 best GA models in solving each benchmark function in Experiment 2. Table 4.4.2 shows the occurrence and performance of GA models in Experiment 2. The calculation for Performance (%) is derived using Formula (1). Table 4.4.3 shows the operation techniques on top 10 GA models.

Benchmark Functions	**GA Models Ranking in Experiment 2**									
	Top 1	**Top 2**	**Top 3**	**Top 4**	**Top 5**	**Top 6**	**Top 7**	**Top 8**	**Top 9**	**Top 10**
B1	GA62	GA56	GA68	GA14	GA32	GA44	GA50	GA26	GA38	GA08
B2	GA68	GA62	GA38	GA44	GA08	GA26	GA50	GA32	GA56	GA14
B3	GA08	GA56	GA68	GA26	GA20	GA14	GA02	GA44	GA32	GA50
B4	GA68	GA50	GA62	GA56	GA44	GA14	GA08	GA02	GA20	GA38
B5	GA68	GA56	GA50	GA62	GA44	GA14	GA02	GA32	GA38	GA67
B6	GA56	GA62	GA14	GA44	GA68	GA26	GA50	GA32	GA20	GA38
B7	GA02	GA56	GA08	GA62	GA68	GA50	GA14	GA44	GA38	GA26
B8	GA68	GA50	GA08	GA56	GA62	GA14	GA32	GA38	GA26	GA02
B9	GA68	GA62	GA44	GA50	GA32	GA14	GA08	GA56	GA38	GA61
B10	GA32	GA50	GA26	GA14	GA62	GA20	GA68	GA38	GA44	GA08

Table 4.4.1 Top 10 GA Models in Experiment 2

GA Model	Ranking in Experiment 2										Occurrence	Performance (%)
	Top 1	Top 2	Top 3	Top 4	Top 5	Top 6	Top 7	Top 8	Top 9	Top 10		
GA61	0	0	0	0	0	0	0	0	0	1	1	1
GA67	0	0	0	0	0	0	0	0	0	1	1	1
GA20	0	0	0	0	1	1	0	0	2	0	4	15
GA02	1	0	0	0	0	0	2	1	0	1	5	22
GA38	0	0	1	0	0	0	0	2	4	2	9	24
GA26	0	0	1	1	0	2	0	1	1	1	7	31
GA32	1	0	0	0	2	0	1	3	1	0	8	37
GA08	1	0	2	0	1	0	2	0	0	2	8	42
GA44	0	0	1	2	2	1	0	2	1	0	9	47
GA14	0	0	1	2	0	5	1	0	0	1	10	52
GA50	0	3	1	1	0	1	3	0	0	1	10	60
GA56	1	4	0	2	0	0	0	1	1	0	9	65
GA62	1	3	1	2	2	0	0	0	0	0	9	71
GA68	5	0	2	0	2	0	1	0	0	0	10	82

Table 4.4.2 Occurrence and Performance of GA Models in Experiment 2

	Selection				Crossover			Mutation			Replacement	
GA model	Roulette Wheel	Random	Rank	Tournament	Single Point	Two Point	Uniform	Flipping	Interchanging	Reversing	Random	Weak Parent
GA61				✔		✔		✔			✔	
GA67				✔			✔	✔			✔	
GA20		✔			✔			✔				✔
GA02	✔				✔			✔				✔
GA38			✔		✔			✔				✔
GA26		✔				✔		✔				✔
GA32		✔					✔	✔				✔
GA08	✔					✔		✔				✔
GA44			✔			✔		✔				✔
GA14	✔						✔	✔				✔
GA50			✔				✔	✔				✔
GA56				✔	✔			✔				✔
GA62				✔		✔		✔				✔
GA68				✔			✔	✔				✔

Table 4.4.3 Operation Techniques of Top 10 GA Models in Experiment 2

4.4.1 Parameter Setting Perspectives

Experiment 2 alters the number of genes from 30 to 10. The dimension of the population in Experiment 2 is 40 x 10. Hence, the diversity of the population is low.

By comparing the result from Table 4.2.1 and Table 4.2.2, the fitness values are dropping drastically and nearer to the optimum values. The main reason is the most of the benchmark functions are summation, so the less the dimension of population, the lower the fitness value of the benchmark functions.

From Table 4.3.3 and Table 4.4.3, the ranking of selection operation, mutation operation and replacement operation is similar. The main difference of these two tables is the crossover operation. In Experiment 2, Two Point Crossover has outperformed Single Point Crossover compared to Two Point Crossover has similar performance to Single Point Crossover in Experiment 1. As mentioned above, the diversity of population in Experiment 2 is low, this makes Two Point Crossover could outperform Single Point Crossover since Two Point Crossover provides more diversity for the children.

4.4.2 Findings on Experiment 2

In Experiment 2, GA68 is still the best GA model in solving optimisation problems with Tournament Selection, Uniform Crossover, Flipping Mutation and Weak Parent Replacement. Furthermore, Single Point Crossover is not a suitable technique to be used when the number of genes is less.

4.5 Analysis and Discussion for Experiment 3

This section includes the analysis and discussion for Experiment 3. The changes parameter setting in Experiment 3 is stated in Table 3.2.2.3. Based on the result of Experiment 3 shown in Table 4.2.3, top 10 GA models for each benchmark functions are identified. Table 4.5.1 shows the 10 best GA models in solving each benchmark function in Experiment 3. Table 4.5.2 shows the occurrence and performance of GA models in Experiment 3. The calculation for Performance (%) is derived using Formula (1). Table 4.5.3 shows the operation techniques on top 10 GA models.

Benchmark Functions	GA Models Ranking in Experiment 3									
	Top 1	Top 2	Top 3	Top 4	Top 5	Top 6	Top 7	Top 8	Top 9	Top 10
B1	GA68	GA62	GA56	GA38	GA50	GA44	GA32	GA14	GA08	GA20
B2	GA68	GA50	GA56	GA62	GA44	GA14	GA38	GA32	GA08	GA26
B3	GA32	GA02	GA38	GA26	GA68	GA14	GA62	GA08	GA20	GA55
B4	GA62	GA68	GA50	GA56	GA44	GA32	GA14	GA38	GA26	GA08
B5	GA68	GA62	GA56	GA50	GA44	GA14	GA32	GA38	GA08	GA02
B6	GA68	GA62	GA38	GA56	GA50	GA14	GA44	GA32	GA02	GA08
B7	GA14	GA08	GA02	GA68	GA62	GA56	GA50	GA44	GA38	GA32
B8	GA68	GA62	GA50	GA56	GA14	GA44	GA32	GA38	GA08	GA26
B9	GA68	GA56	GA62	GA50	GA44	GA32	GA14	GA38	GA26	GA08
B10	GA32	GA50	GA62	GA44	GA14	GA56	GA68	GA38	GA08	GA26

Table 4.5.1 Top 10 GA Models in Experiment 3

GA Model	Ranking in Experiment 3										Occurrence	Performance (%)
	Top 1	Top 2	Top 3	Top 4	Top 5	Top 6	Top 7	Top 8	Top 9	Top 10		
GA55	0	0	0	0	0	0	0	0	0	1	1	1
GA20	0	0	0	0	0	0	0	0	1	1	2	3
GA26	0	0	0	1	0	0	0	0	2	3	6	14
GA02	0	1	1	0	0	0	0	0	1	1	4	20
GA08	0	1	0	0	0	0	0	1	5	3	10	25
GA38	0	0	2	1	0	0	1	5	1	0	10	44
GA44	0	0	0	1	4	2	1	1	0	0	9	48
GA32	2	0	0	0	0	2	3	2	0	1	10	49
GA14	1	0	0	0	2	4	2	1	0	0	10	53
GA56	0	1	3	3	0	2	0	0	0	0	9	64
GA50	0	2	2	2	2	0	1	0	0	0	9	64
GA62	1	4	2	1	1	0	1	0	0	0	10	79
GA68	6	1	0	1	1	0	1	0	0	0	10	86

Table 4.5.2 Occurrence and Performance of GA Models in Experiment 3

	Selection				Crossover			Mutation			Replacement	
GA model	Roulette Wheel	Random	Rank	Tournament	Single Point	Two Point	Uniform	Flipping	Interchanging	Reversing	Random	Weak Parent
GA55				✔	✔			✔			✔	
GA20		✔			✔			✔				✔
GA26		✔				✔		✔				✔
GA02	✔				✔			✔				✔
GA08	✔					✔		✔				✔
GA38			✔		✔			✔				✔
GA44			✔			✔		✔				✔
GA32		✔					✔	✔				✔
GA14	✔						✔	✔				✔
GA50			✔				✔	✔				✔
GA56				✔	✔			✔				✔
GA62				✔		✔		✔				✔
GA68				✔			✔	✔				✔

Table 4.5.3 Operation Techniques of Top 10 GA Models in Experiment 3

4.5.1 Parameter Setting Perspectives

In Experiment 3, the altered parameters setting is the maximum generation, which increases from 2,000 to 10,000. By comparing the performance of operation techniques, GA68 is still the best model in this experiment.

The best fitness value of each benchmark function obtained from this experiment is nearer to the optimum value compared to the result obtained in Experiment 1. The difference of the best fitness value between these two experiments is actually big. Hence, maximum generation has a great influence on the final fitness value of the population. Number of the generation determines how many evolutions the population could have. The more the evolutions, the better the final fitness value of a population.

4.5.2 Findings on Experiment 3

In Experiment 3, GA68 is still the best GA model in solving optimisation problems with Tournament Selection, Uniform Crossover, Flipping Mutation and Weak Parent Replacement. In addition, number of maximum generation is a major factor of affecting the fitness value of benchmark functions.

4.6 Overall Experimental Result and Findings

In this section, the result of three experiments are combined together to see the overall performance. The result as shown in Table 4.3.2, Table 4.4.2 and Table 4.5.2 are merged by summation and shown in Table 4.6.1. Due to the compilation of three experimental results, the total occurrence of GA model is replaced with 30 in Formula (1) because the total occurrence of each GA model able to appear in 10 benchmark function is 30. Table 4.6.1 shows the total occurrence and performance of GA models in three experiments.

GA Model	Ranking in Three Experiments										Occurrence	Performance (%)
	Top 1	Top 2	Top 3	Top 4	Top 5	Top 6	Top 7	Top 8	Top 9	Top 10		
GA55	0	0	0	0	0	0	0	0	0	1	1	0.33
GA61	0	0	0	0	0	0	0	0	0	3	3	1.00
GA67	0	0	0	0	0	0	0	0	7	3	10	5.67
GA20	0	0	0	0	1	1	0	0	4	1	7	6.67
GA26	0	0	1	2	0	2	0	1	3	4	13	15.00
GA02	1	2	1	1	0	0	2	1	1	2	11	19.33
GA08	2	1	3	0	1	0	2	1	6	10	26	30.67
GA38	0	0	3	1	0	0	1	16	6	2	29	32.33
GA32	3	0	0	0	2	7	7	5	1	2	27	41.33
GA44	0	0	1	3	12	3	3	4	1	0	27	47.33
GA14	2	1	1	3	3	12	6	1	0	1	30	54.67
GA50	0	6	4	9	3	1	5	0	0	1	29	64.33
GA56	1	6	9	6	1	3	0	1	1	0	28	68.00
GA62	2	13	5	3	4	1	1	0	0	0	29	77.00
GA68	19	1	2	2	3	0	3	0	0	0	30	86.33

Table 4.6.1 Occurrence of GA Models in the Experiments

From Table 4.6.1, GA68 is the best GA model among all the combinations of operation techniques. GA68 has the best performance for 19 out of 30 benchmark functions testing. This shows that GA68 is able to fully optimise most of the benchmark functions. GA62, GA56 and GA50 are also having great performance towards the benchmark functions. GA14, GA44 and GA32 are mainly appearing in the middle ranking. Most of the appearance of GA32 and GA08 are in lower ranking. From this information, the priority of selecting operation techniques can be derived. For example, in GA68, GA62 and GA56, most of the operations are same and the only different GA operation is the crossover. GA68 is Uniform Crossover, GA62 is Two Point Crossover, and GA56 is Single Point Crossover. This shows that crossover operation is the main factor of affecting the performance in the upper ranking GA models. In other word, crossover operation has the least influence in affecting the performance of GA models since it only influence the ranking when the other operation techniques remain the same. From Table 4.3.3, mutation operation is the most important operation, followed by replacement operation and selection operation, and the least important operation is crossover operation.

4.7 Summary

Based on the analysis and discussion above, GA68 has been concluded as the best combination of operation techniques with Tournament Selection, Uniform Crossover, Flipping Mutation and Weak Parent Replacement. However, other GA models could outperform GA68 in certain circumstances such as decreases the dimension of population and increases the number of maximum generation. In this project, two additional distinct experiments are conducted with different parameters setting which are the number of gene and number of maximum generation. Through the comparison between the results of three experiments, it is concluded that parameters setting are able to indirectly affect the performance of GA models. The operation that the most affecting the performance of GA model is the mutation. Hence, the selecting of mutation operation techniques should be considered first in implementing GA in the research.

Chapter 5 Conclusion and Future Works

Optimisation problem is a concerning topic in this highly competitive modern world. By solving the optimisation problem, an organisation is able to minimise the cost and maximise the profit. Common methods used to solve the optimisation problem are mathematical methods and AI methods, and GA is one of the popular AI methods. In GA, there are few techniques on different operation and the performance of GA model is affected by the techniques applied. Most of researchers do not consider the performance of GA in their works. In consequence, the researchers are unable to obtain the optimum result and take longer time to get result. Hence, it is important to explore the combinations of different operation techniques and test their performance. By identifying the performance of each combination, this helps the researchers as a guideline to select an appropriate GA model and improve the efficiency and accuracy of their research.

This project aims to analyse the operation techniques and identify their performance of solving optimisation problems. Based on the experiments result, different operation techniques applied will affect the performance of the GA model. As discussed in the previous section, the best GA model is identified based on the ability of optimising the benchmark functions. Furthermore, GA68 which consists of Tournament Selection, Uniform Crossover, Flipping Mutation and Weak Parent Replacement, is concluded as the best GA model after running the experiments. GA68 is still able to have the best performance among the GA models with the changes of parameters setting. However, other GA models are slightly affected.

To improve the performance of GA towards the optimisation problem, other operation techniques can be tested and parameters setting can be modified. The identified good GA models are can also be implemented in different case studies and more benchmark functions to further prove their good performance. In addition, the best GA model determined in this project will be used to compare with the others mathematical and optimisation methods.

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Appendices

Appendix A GA Models with Combinations of Different Operation Techniques

GA model	Selection				Crossover			Mutation			Replacement	
	Roulette Wheel	Random	Rank	Tournament	Single Point	Two Point	Uniform	Flipping	Interchanging	Reversing	Random	Weak Parent
GA01	✔				✔			✔			✔	
GA02	✔				✔			✔				✔
GA03	✔				✔				✔		✔	
GA04	✔				✔				✔			✔
GA05	✔				✔					✔	✔	
GA06	✔				✔					✔		✔
GA07	✔					✔		✔			✔	
GA08	✔					✔		✔				✔
GA09	✔					✔			✔		✔	
GA10	✔					✔			✔			✔
GA11	✔					✔				✔	✔	
GA12	✔					✔				✔		✔
GA13	✔						✔	✔			✔	
GA14	✔						✔	✔				✔
GA15	✔						✔		✔		✔	
GA16	✔						✔		✔			✔
GA17	✔						✔			✔	✔	
GA18	✔						✔			✔		✔
GA19		✔			✔			✔			✔	

GA model	Selection				Crossover			Mutation			Replacement	
	Roulette Wheel	Random	Rank	Tournament	Single Point	Two Point	Uniform	Flipping	Interchanging	Reversing	Random	Weak Parent
GA20		✔			✔			✔				✔
GA21		✔			✔				✔		✔	
GA22		✔			✔				✔			✔
GA23		✔			✔					✔	✔	
GA24		✔			✔					✔		✔
GA25		✔				✔		✔			✔	
GA26		✔				✔		✔				✔
GA27		✔				✔			✔		✔	
GA28		✔				✔			✔			✔
GA29		✔				✔				✔	✔	
GA30		✔				✔				✔		✔
GA31		✔					✔	✔			✔	
GA32		✔					✔	✔				✔
GA33		✔					✔		✔		✔	
GA34		✔					✔		✔			✔
GA35		✔					✔			✔	✔	
GA36		✔					✔			✔		✔
GA37			✔		✔			✔			✔	
GA38			✔		✔			✔				✔
GA39			✔		✔				✔		✔	
GA40			✔		✔				✔			✔
GA41			✔		✔					✔	✔	
GA42			✔		✔					✔		✔

GA model	Selection				Crossover			Mutation			Replacement	
	Roulette Wheel	Random	Rank	Tournament	Single Point	Two Point	Uniform	Flipping	Interchanging	Reversing	Random	Weak Parent
GA43			✔			✔		✔			✔	
GA44			✔			✔		✔				✔
GA45			✔			✔			✔		✔	
GA46			✔			✔			✔			✔
GA47			✔			✔				✔	✔	
GA48			✔			✔				✔		✔
GA49			✔				✔	✔			✔	
GA50			✔				✔	✔				✔
GA51			✔				✔		✔		✔	
GA52			✔				✔		✔			✔
GA53			✔				✔			✔	✔	
GA54			✔				✔			✔		✔
GA55				✔	✔			✔			✔	
GA56				✔	✔			✔				✔
GA57				✔	✔				✔		✔	
GA58				✔	✔				✔			✔
GA59				✔	✔					✔	✔	
GA60				✔	✔					✔		✔
GA61				✔		✔		✔			✔	
GA62				✔		✔		✔				✔
GA63				✔		✔			✔		✔	
GA64				✔		✔			✔			✔
GA65				✔		✔				✔	✔	

GA model	Selection				Crossover			Mutation			Replacement	
	Roulette Wheel	Random	Rank	Tournament	Single Point	Two Point	Uniform	Flipping	Interchanging	Reversing	Random	Weak Parent
GA66				✔		✔				✔		✔
GA67				✔			✔	✔			✔	
GA68				✔			✔	✔				✔
GA69				✔			✔		✔		✔	
GA70				✔			✔		✔			✔
GA71				✔			✔			✔	✔	
GA72				✔			✔			✔		✔

Appendix B Experimental Result

Appendix B-1 Experiment 1 Result

GA MODELS	B1			B2			B3			B4			B5		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA01	19.7990	20.5658	0.2045	600.1127	1074.4686	0.1912	0.0001	0.0016	0.2239	66460.2720	167134.2934	0.3134	38.0791	91.3403	0.1795
GA02	7.8775	9.3321	0.1900	30.3377	66.7076	0.1865	0.0000	0.0002	0.2045	5680.6259	10450.9357	0.2944	2.4332	4.8678	0.1640
GA03	19.7783	20.7719	0.1662	759.4599	1808.8572	0.1582	0.0028	0.1306	0.1698	88425.6220	260268.2325	0.2253	76.3782	126.2203	0.1470
GA04	13.2495	16.7463	0.1686	117.2820	273.5065	0.1579	0.0003	0.0123	0.1718	14885.3995	41928.7064	0.2217	15.4204	41.1738	0.1539
GA05	20.2285	20.9131	0.1527	545.0667	1912.4012	0.1604	0.0136	0.2255	0.1745	209892.5191	304655.3488	0.2205	71.8321	132.3706	0.1408
GA06	15.6049	17.7237	0.1633	195.8942	540.9572	0.1648	0.0018	0.0304	0.1741	21318.4050	77757.5509	0.2228	43.1386	66.3515	0.1430
GA07	19.8549	20.5360	0.1865	528.5500	936.9835	0.1808	0.0001	0.0021	0.2054	65136.9653	145008.5795	0.3002	31.4968	82.1586	0.1637
GA08	7.4515	9.0525	0.1841	24.7054	56.9210	0.1815	0.0000	0.0001	0.2110	4509.6105	8704.1119	0.3040	2.5762	4.1031	0.1637
GA09	20.1224	20.9100	0.1634	633.1184	1457.8850	0.1601	0.0207	0.1081	0.1738	137214.8158	250615.5782	0.2230	35.8298	105.3716	0.1435
GA10	11.9307	15.3709	0.1624	70.6125	235.1428	0.1665	0.0001	0.0093	0.1710	17571.0977	40666.6981	0.2206	12.1494	35.1176	0.1414
GA11	20.0570	20.8202	0.1591	839.2989	1691.8192	0.1597	0.0184	0.1770	0.1724	126154.1094	263071.7535	0.2319	81.9690	134.6518	0.1513
GA12	14.1851	16.7542	0.1635	137.9576	303.9951	0.1600	0.0007	0.0232	0.1710	24959.4102	54506.3243	0.2279	22.5949	46.1619	0.1475
GA13	20.0582	20.5549	0.1950	492.7114	945.6736	0.1837	0.0000	0.0020	0.2160	61633.8829	144895.0326	0.3167	35.4284	78.4501	0.1764
GA14	5.3491	7.6445	0.1923	15.3953	35.8303	0.1895	0.0000	0.0002	0.2092	3215.0558	6099.2578	0.3218	1.7206	2.9309	0.1744
GA15	20.2291	20.8394	0.1691	574.9730	1308.3469	0.1635	0.0011	0.0493	0.1782	95776.1393	210151.9125	0.2615	35.8980	95.1249	0.1601
GA16	7.8632	11.7919	0.1691	18.6073	115.8378	0.1679	0.0000	0.0048	0.1815	4978.3555	19917.5297	0.3012	2.0670	14.8198	0.1623
GA17	20.2586	20.8484	0.1686	745.7791	1365.3839	0.1746	0.0012	0.0485	0.1875	54046.0537	202692.7850	0.3093	36.4264	96.0892	0.1648
GA18	9.3782	12.7932	0.1651	26.8292	127.5511	0.1737	0.0001	0.0039	0.1826	5561.4601	25989.2287	0.3045	7.5358	17.6204	0.1627
GA19	20.1272	20.6492	0.1840	1709.3754	3019.2138	0.1790	0.5376	1.2836	0.2051	354256.5121	480924.4823	0.3917	152.8524	203.3372	0.1639
GA20	7.7617	9.2822	0.1862	43.1583	74.2609	0.1784	0.0000	0.0003	0.2053	6105.0665	11583.4175	0.3985	3.2076	5.0941	0.1714
GA21	19.9678	20.8772	0.1638	2971.5441	3622.0897	0.1492	0.9036	2.2314	0.1780	281754.8623	568091.2922	0.2892	142.3577	238.0418	0.1781
GA22	13.6186	16.8952	0.1583	92.8484	266.1507	0.2002	0.0005	0.0034	0.2175	12162.8161	46641.9211	0.2908	4.8264	36.2597	0.1810
GA23	20.3741	20.9113	0.1662	1540.2704	3941.5032	0.1932	0.6860	2.4202	0.2130	401019.5626	673054.4563	0.2909	180.0732	253.1406	0.1852
GA24	15.4773	17.8317	0.1952	211.6010	458.8516	0.1941	0.0004	0.0394	0.2171	31218.2530	85107.0743	0.2865	23.1496	59.7789	0.1824

GA MODELS	B1			B2			B3			B4			B5		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA25	20.0101	20.5863	0.2339	1798.4317	2965.4126	0.2252	0.2669	1.1979	0.2575	309271.2448	472027.3177	0.3983	128.7439	196.5190	0.2119
GA26	6.7585	8.9080	0.2377	29.3120	58.9198	0.2268	0.0000	0.0003	0.2609	6912.7327	9865.3040	0.4005	2.5593	4.3026	0.2128
GA27	20.2455	20.8773	0.2016	2259.3107	3760.4597	0.1978	0.1641	2.3823	0.2170	390987.1308	615386.8626	0.2918	143.3889	244.4179	0.1835
GA28	10.1172	14.9546	0.1975	84.3957	226.8511	0.2070	0.0001	0.0069	0.2182	9481.0306	34719.6631	0.2905	7.7796	25.5033	0.1867
GA29	20.6325	21.0615	0.2078	2187.2282	3671.5649	0.1973	0.1518	2.2919	0.2125	334774.6185	619962.9057	0.2921	166.3364	250.7347	0.1950
GA30	13.7201	16.6319	0.1997	116.8157	319.9735	0.1943	0.0005	0.0156	0.2220	18842.7151	58003.5828	0.2938	18.7697	42.3545	0.1910
GA31	19.7142	20.5197	0.2482	1907.3859	2773.5217	0.2376	0.2155	1.1193	0.2696	360107.7443	492006.7229	0.4062	151.2437	205.7963	0.2255
GA32	6.2293	7.7170	0.2381	19.7571	35.7163	0.2338	0.0000	0.0003	0.2660	2952.8685	5831.3712	0.3856	1.6412	3.0125	0.2171
GA33	20.3738	20.9094	0.2103	3035.3111	3842.1841	0.2108	0.4148	2.3957	0.2235	320606.9771	604812.9631	0.2896	175.1985	258.8741	0.1934
GA34	7.0165	11.6907	0.2071	28.0852	115.0005	0.2052	0.0000	0.0028	0.2312	8407.7019	19048.3630	0.2906	1.7928	10.0656	0.1981
GA35	20.4104	20.9125	0.2084	2082.0314	3736.2555	0.2024	0.9138	2.1596	0.2218	329051.4821	546279.4376	0.2877	155.6519	234.9150	0.1887
GA36	9.8053	12.7641	0.2083	34.9169	105.6458	0.2062	0.0000	0.0039	0.2224	4987.2313	18742.0463	0.2889	5.4377	16.5744	0.1954
GA37	13.4031	15.0874	0.2405	188.3086	309.1422	0.2293	0.0002	0.0031	0.2632	35740.0254	53274.6559	0.3948	16.6642	25.7369	0.2122
GA38	6.8709	8.0256	0.2467	16.9673	39.7916	0.2354	0.0000	0.0003	0.2588	2943.8582	6298.6470	0.3670	1.3335	3.0300	0.2242
GA39	12.9896	16.5009	0.2007	364.8903	737.7060	0.1999	0.0013	0.0547	0.2255	23715.9484	113797.9855	0.2833	13.7033	48.2043	0.1941
GA40	13.9280	18.2948	0.2067	81.3579	258.2206	0.2108	0.0000	0.0085	0.2199	19564.2435	43866.4901	0.2842	17.3215	60.5847	0.2048
GA41	16.9691	18.6248	0.2047	694.0421	1219.2115	0.1997	0.0184	0.1402	0.2185	100935.4773	192150.7292	0.2872	30.2781	82.7062	0.1898
GA42	15.8535	18.3649	0.2044	131.4642	484.9681	0.2006	0.0001	0.0250	0.2250	23979.4093	81883.6736	0.2834	30.9289	71.5568	0.1916
GA43	11.1996	14.3732	0.2444	204.1060	323.1931	0.2339	0.0002	0.0029	0.2617	23585.5334	50099.6641	0.3740	15.8365	23.7963	0.2209
GA44	6.4835	7.5912	0.2386	16.7845	35.6098	0.2314	0.0000	0.0004	0.2705	3076.1076	5510.7016	0.4024	1.4697	2.8261	0.2211
GA45	13.5331	16.0830	0.2132	328.5192	571.8658	0.2018	0.0007	0.0474	0.2131	41521.9206	89436.8208	0.3043	13.1708	35.8645	0.1898
GA46	14.3735	17.0524	0.2295	57.2245	236.7947	0.2020	0.0000	0.0038	0.2163	10683.3905	34349.4830	0.3261	9.6200	40.9918	0.1957
GA47	15.4473	17.6994	0.2113	507.4099	988.1893	0.2032	0.0034	0.1254	0.2167	67722.1638	144054.8311	0.2618	29.6473	67.0244	0.1952
GA48	16.2102	17.9591	0.2272	63.2764	302.8761	0.2003	0.0001	0.0291	0.2284	14422.0509	56962.2323	0.2821	36.8010	60.0800	0.1930
GA49	12.1732	13.9679	0.2583	169.8859	265.1095	0.2458	0.0003	0.0025	0.2652	30767.1871	45277.8213	0.4064	13.3970	22.4810	0.2287
GA50	5.4763	6.8024	0.2468	14.8402	26.9095	0.2376	0.0000	0.0002	0.2739	2325.6510	3859.4262	0.3909	1.0586	2.0077	0.2265
GA51	10.4036	14.0417	0.2122	141.9545	406.7558	0.2109	0.0008	0.0249	0.2262	25714.2827	72925.4775	0.2931	3.5324	25.2711	0.2012
GA52	8.1440	14.1547	0.2113	41.4895	138.3121	0.2085	0.0000	0.0036	0.2246	5370.5314	22860.5846	0.2977	2.3478	18.1194	0.1979
GA53	9.4003	14.9814	0.2128	151.1882	424.5693	0.2152	0.0001	0.0296	0.2341	14325.3554	71482.7502	0.2998	10.0049	30.3880	0.2058
GA54	11.6570	15.4856	0.2135	11.9048	112.3463	0.2105	0.0000	0.0036	0.2285	8352.9771	24260.4455	0.2920	10.2625	29.9320	0.2016

GA MODELS	B1			B2			B3			B4			B5		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA55	8.0004	9.0725	0.2476	26.9173	57.4312	0.2373	0.0000	0.0006	0.2299	5115.5912	9544.4707	0.3979	2.7373	4.8065	0.2359
GA56	5.1370	6.2651	0.2538	11.0661	21.0472	0.2461	0.0000	0.0002	0.2092	1627.0341	3661.9924	0.3932	0.9677	1.4622	0.2346
GA57	13.0222	15.9892	0.2151	148.7401	506.3466	0.2107	0.0020	0.0295	0.1736	33112.0480	78790.1342	0.2932	8.6957	43.3144	0.2076
GA58	17.4333	18.9035	0.2148	51.7999	285.0272	0.2121	0.0000	0.0070	0.1755	8478.2652	40971.4808	0.3008	26.7497	82.0588	0.2045
GA59	16.6093	18.7303	0.2098	615.0213	1171.1150	0.2089	0.0072	0.1435	0.1745	137383.6970	214152.3859	0.2910	37.1524	85.8914	0.2005
GA60	17.6596	19.0192	0.2160	302.8222	652.0072	0.2138	0.0023	0.0418	0.1732	34459.1420	117354.7043	0.3047	45.1477	90.6008	0.1978
GA61	6.5093	8.7609	0.2530	25.5004	53.5962	0.2437	0.0000	0.0008	0.2108	4893.9283	8794.3032	0.3954	2.5738	4.3874	0.2326
GA62	4.8393	6.5080	0.2478	10.9479	19.0371	0.2406	0.0000	0.0002	0.2045	1817.8908	3220.5887	0.3958	0.7003	1.3902	0.2328
GA63	6.2586	14.7563	0.2141	89.1656	396.5758	0.2133	0.0004	0.0489	0.1696	14334.3458	83173.9279	0.2985	9.9750	41.4785	0.2055
GA64	15.7513	18.4958	0.2194	58.9054	230.0261	0.2153	0.0000	0.0113	0.1716	10200.1716	42741.1632	0.2980	23.1017	60.8227	0.2031
GA65	14.9342	17.8524	0.2138	456.3991	888.3606	0.2207	0.0028	0.0677	0.1710	47317.1025	131910.1862	0.2964	36.7619	68.6132	0.2023
GA66	16.3272	18.2698	0.2162	131.6224	357.3589	0.2130	0.0001	0.0299	0.1856	22494.3846	63580.9424	0.3021	39.9769	71.2214	0.1994
GA67	6.5855	8.2804	0.2610	24.0057	48.9656	0.2516	0.0000	0.0005	0.2233	4845.0939	8285.9591	0.3977	2.0192	3.8595	0.2273
GA68	4.4480	5.9745	0.2536	9.0030	18.0104	0.2559	0.0000	0.0003	0.2268	1043.0521	2681.9142	0.4023	0.6674	1.2517	0.2390
GA69	6.7303	12.9308	0.2217	83.5293	365.7294	0.2140	0.0001	0.0107	0.1883	17496.6545	51894.3242	0.3049	2.5063	17.4455	0.1929
GA70	12.3249	16.3486	0.2205	23.9541	164.0408	0.2222	0.0001	0.0071	0.2118	8083.7830	25014.4498	0.3140	3.7413	29.5763	0.1961
GA71	10.0783	14.5183	0.2279	125.6687	311.6310	0.2194	0.0003	0.0144	0.2426	4033.8665	56250.5039	0.3103	10.6832	27.6314	0.2196
GA72	13.1826	16.7547	0.2203	29.1079	156.0514	0.2235	0.0000	0.0065	0.2371	10249.7148	28833.9211	0.3123	14.5679	41.5213	0.2222

GA MODELS	B6			B7			B8			B9			B10		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA01	309.2776	376.3562	0.1939	70.0014	182.4565	0.1855	73.5348	109.4404	0.2002	137.3509	293.4416	0.2127	2.1701	9.5701	0.1993
GA02	48.0757	61.7298	0.1848	1.6123	3.9270	0.1729	10.1685	16.0545	0.2374	9.5232	16.0892	0.2119	0.3033	0.7113	0.2085
GA03	276.6152	410.3113	0.1628	231.2554	389.3162	0.1529	76.4714	136.9287	0.1891	212.1731	437.6798	0.1654	13.4276	45.3980	0.1832
GA04	126.3025	225.0669	0.1621	217.1710	417.1895	0.1506	42.7227	76.3149	0.1784	62.9095	151.6045	0.1657	0.7884	6.1232	0.1638
GA05	358.4057	448.4736	0.1600	297.1809	434.0371	0.1501	111.6911	156.2196	0.1850	238.5133	433.9321	0.1745	27.2019	65.3997	0.1760
GA06	159.8391	245.3235	0.1622	254.9081	514.3538	0.1512	60.0237	97.0103	0.1960	80.9480	203.6059	0.1731	4.3231	17.9967	0.1582
GA07	314.2287	381.0912	0.1867	108.3043	194.2652	0.1743	57.5610	107.5060	0.2219	140.5754	281.0244	0.2026	1.7979	8.8006	0.1884
GA08	44.5725	58.6608	0.1877	1.4033	4.0151	0.1740	11.0946	14.8975	0.1978	8.0855	15.5948	0.2024	0.3656	0.7092	0.2049
GA09	274.6435	404.2283	0.1613	184.5968	377.3751	0.1514	87.9024	155.6076	0.1679	207.7523	355.9424	0.1642	7.7918	34.4515	0.1720
GA10	67.8979	165.6508	0.1743	222.8660	388.6146	0.1517	25.7331	61.4780	0.1689	26.9300	125.1517	0.1670	1.5419	6.0260	0.1681
GA11	316.8507	438.2605	0.1635	215.1188	392.7839	0.1557	98.9810	150.6401	0.1654	207.2128	415.4092	0.1699	7.5391	52.9227	0.1709
GA12	116.6713	194.7266	0.1663	225.9413	428.1974	0.1532	55.2674	83.0797	0.1799	88.1094	153.0889	0.1694	3.1927	11.4194	0.1724
GA13	279.0428	378.4584	0.1955	95.3405	196.1169	0.1805	76.8689	111.2673	0.2057	108.4035	267.2903	0.1960	1.5118	7.1021	0.2086
GA14	36.4052	47.1482	0.1981	1.2016	3.1355	0.1802	8.5272	11.9181	0.2010	5.3965	9.8704	0.2047	0.2375	0.5137	0.2002
GA15	289.6843	400.0885	0.1698	184.0419	357.2660	0.1580	83.0242	132.9560	0.1776	95.0655	360.3166	0.1797	4.7901	23.9150	0.1903
GA16	38.3365	81.2145	0.1724	189.4293	301.9741	0.1593	12.6784	35.5868	0.1792	8.4391	42.4887	0.1700	1.1248	3.0522	0.1799
GA17	307.2671	393.5571	0.1779	228.2325	385.6614	0.1620	68.5236	142.7401	0.1756	109.4707	342.7494	0.1821	8.1268	30.1436	0.1847
GA18	51.6004	102.7061	0.1807	204.0164	331.2637	0.1641	20.0317	44.8728	0.1799	28.5013	73.2455	0.1789	1.2029	4.2986	0.1786
GA19	378.0983	468.1618	0.1869	297.8191	300139.5190	0.1757	160.5204	301.6054	0.1902	553.8638	683.4823	0.2221	94.8057	165.8778	0.2175
GA20	46.0452	65.3383	0.1928	19.1297	35.4329	0.1680	13.7241	18.0389	0.2054	9.0530	19.5475	0.2432	0.3431	0.8794	0.2494
GA21	369.1676	544.0464	0.1602	553.7378	1850139.6329	0.1491	223.4386	793.0001	0.1733	557.2011	838.5062	0.2158	131.4149	213.9156	0.2052
GA22	121.8860	209.3305	0.1979	89.6861	231.4150	0.1457	28.8440	64.4704	0.1697	34.7906	150.7057	0.2067	2.2544	5.9208	0.2065
GA23	395.7565	536.0600	0.2086	2926.5108	1999982.4044	0.1559	142.1807	805.8164	0.1707	687.5547	864.7193	0.2149	94.0841	248.8873	0.2098
GA24	137.7695	224.3793	0.2061	164.7986	273.7420	0.1843	51.1108	79.6854	0.1785	140.3762	205.4443	0.2220	2.7851	13.9081	0.1983
GA25	409.1169	478.0207	0.2378	593.5542	452919.0435	0.2222	117.9553	366.9371	0.2004	411.4053	665.4558	0.2499	85.4335	149.4635	0.2401
GA26	42.1622	60.7371	0.2396	16.4293	29.6448	0.2185	10.7558	15.9620	0.2027	8.6762	17.6279	0.2459	0.4102	0.7960	0.2537
GA27	398.4214	543.2350	0.2065	33362.1367	2606684.8271	0.1939	177.9655	828.5039	0.1832	472.0726	789.8362	0.2130	99.4804	211.7313	0.2134
GA28	69.2377	143.3036	0.2079	76.5221	190.1382	0.1868	23.3675	54.1637	0.2247	34.0223	107.2684	0.2163	1.4497	4.8882	0.2105
GA29	445.4868	537.5300	0.2091	8124.9271	2263701.2334	0.1921	179.4116	821.8354	0.2171	563.2901	825.7177	0.2114	105.1781	226.7315	0.2027

GA MODELS	B6			B7			B8			B9			B10		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA30	122.4120	197.0099	0.2068	140.3931	208.3011	0.1917	42.7522	75.3570	0.2200	66.9850	158.8560	0.2066	3.3634	9.1407	0.2055
GA31	413.4009	474.9812	0.2478	3733.2988	421136.0911	0.2252	126.7468	398.8238	0.2786	445.2173	681.9773	0.2503	85.9398	146.5188	0.2510
GA32	31.5285	46.4008	0.2476	12.5527	23.4825	0.2281	8.4977	12.2510	0.2715	5.1187	10.3254	0.2519	0.1953	0.5280	0.2494
GA33	417.1017	525.6108	0.2148	383.9982	2249353.8304	0.1995	120.5450	900.8573	0.2266	598.9834	861.3359	0.2168	55.5426	193.7475	0.2199
GA34	31.6752	73.8957	0.2127	10.8750	87.6341	0.1966	16.5031	33.0196	0.2188	5.6678	29.5432	0.2124	0.6389	2.1708	0.2047
GA35	423.3118	536.9339	0.2163	562.3428	2075233.7175	0.1949	215.1703	824.2542	0.2354	589.7883	848.5047	0.2246	104.3271	216.2186	0.2304
GA36	57.8014	95.8371	0.2121	35.7882	101.5685	0.1982	15.3273	40.2616	0.2163	19.9300	54.8634	0.2189	0.4989	3.2760	0.2304
GA37	104.1420	135.6827	0.2436	68.8175	160.4380	0.2266	28.7978	39.7676	0.2700	45.8238	84.4540	0.2465	3.0388	4.9268	0.2436
GA38	36.5581	50.5315	0.2391	7.2997	17.7342	0.2280	8.5140	12.9394	0.2659	7.8858	11.6070	0.2937	0.2849	0.6077	0.2507
GA39	59.1160	195.4126	0.2043	146.6723	316.8447	0.1951	36.3745	78.4071	0.2205	43.7436	173.5157	0.2165	1.8322	22.3072	0.2058
GA40	137.8209	261.4353	0.2103	133.4195	266.2947	0.1928	45.4370	77.3021	0.2162	79.4162	183.8887	0.2046	1.9705	7.1051	0.2117
GA41	221.7223	285.2590	0.2109	212.2626	378.4361	0.1929	77.0880	127.8379	0.2116	153.6104	278.2881	0.2106	14.5236	42.2377	0.2123
GA42	180.3073	271.2924	0.2110	161.4406	297.0268	0.1954	56.0619	102.9043	0.2185	136.2760	257.1312	0.2089	4.9676	17.7225	0.2126
GA43	96.2380	129.5469	0.2452	87.3626	153.4214	0.2276	27.7203	42.5133	0.2570	32.1695	83.8887	0.2500	2.2099	5.1212	0.2429
GA44	27.1495	46.3963	0.2422	8.0441	16.3114	0.2264	8.3920	11.7614	0.2749	7.0895	11.0253	0.2548	0.2245	0.6028	0.2467
GA45	110.1128	173.4099	0.2077	153.7540	282.1704	0.1945	26.4704	71.1465	0.2186	44.4543	134.8776	0.2088	4.2736	19.8678	0.2155
GA46	118.4245	199.2199	0.2077	102.9343	230.8265	0.1948	30.7046	66.8401	0.2319	64.6533	163.4162	0.2091	1.5909	5.8038	0.2134
GA47	159.4674	233.9705	0.2102	213.5373	347.0059	0.1998	54.3798	116.9182	0.2114	135.6769	209.5676	0.2183	6.9180	23.4536	0.2063
GA48	161.4230	247.7187	0.2087	107.6443	256.4615	0.1952	43.8285	90.7790	0.2179	96.2329	202.0682	0.2086	4.3757	12.3571	0.2076
GA49	85.0020	115.2396	0.2547	100.3861	172.8708	0.2290	27.4791	35.7335	0.2604	54.2823	73.5912	0.2544	1.6388	4.0966	0.2552
GA50	28.3994	39.2372	0.2536	5.9522	11.0430	0.2355	7.5894	10.6123	0.2617	4.6060	7.7331	0.2631	0.2260	0.4610	0.2568
GA51	68.4305	130.4825	0.2185	87.3574	236.1068	0.2025	25.6912	52.5689	0.2394	37.7504	82.4519	0.2174	2.7621	13.2121	0.2193
GA52	61.1284	121.3961	0.2201	56.3444	143.6713	0.2012	19.6428	43.9621	0.2340	18.2398	60.2818	0.2197	0.8296	3.7578	0.2064
GA53	73.2435	148.1910	0.2186	134.6432	246.5469	0.2037	37.6821	72.6112	0.2295	36.4679	105.3109	0.2207	1.0717	10.1376	0.2218
GA54	74.4687	144.3179	0.2161	80.3192	149.1585	0.2044	30.4472	52.5924	0.2290	21.3730	101.0773	0.2202	1.0117	4.5483	0.2144
GA55	42.6756	64.7225	0.2514	15.0458	26.9037	0.2349	11.5225	17.3283	0.2875	7.7401	17.2736	0.2586	0.3430	0.7987	0.2497
GA56	27.9756	39.2666	0.2573	3.9034	8.5466	0.2368	7.6355	10.1881	0.2703	3.7363	6.4050	0.2567	0.1649	0.5202	0.2555
GA57	95.4996	150.3380	0.2220	156.0699	317.8449	0.2027	27.6480	71.4214	0.2371	29.7911	145.5856	0.2245	4.3201	22.5792	0.2267
GA58	159.7637	276.7860	0.2230	145.1381	305.7025	0.2013	44.1662	85.7065	0.2342	65.1783	254.5194	0.2077	2.5637	9.3327	0.2200
GA59	214.8234	274.4067	0.2240	138.0702	363.4678	0.2033	49.8398	109.4024	0.2319	163.2451	289.3996	0.2178	11.1406	49.8297	0.2235

GA MODELS	B6			B7			B8			B9			B10		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA60	258.7354	316.3794	0.2211	231.1875	337.2080	0.2055	60.9355	111.1539	0.2445	186.2786	337.0832	0.2063	6.0637	25.0092	0.2273
GA61	49.4784	64.7981	0.2512	14.5882	26.0637	0.2395	12.2705	16.1466	0.2707	8.7516	17.9310	0.2578	0.3877	0.7897	0.2542
GA62	23.2021	37.5534	0.2575	2.8421	7.5268	0.2416	5.5608	9.5531	0.2857	3.7165	6.0367	0.2549	0.2084	0.4833	0.2362
GA63	66.9871	125.9325	0.2205	95.7924	283.8206	0.2077	23.0880	55.3544	0.2337	21.8256	108.7168	0.2223	8.6403	20.9412	0.2127
GA64	122.8809	262.2478	0.2221	140.6803	292.9008	0.2099	46.3749	85.0314	0.2419	32.5246	201.8441	0.2206	1.5456	7.6035	0.2201
GA65	172.6542	233.0047	0.2229	157.0860	332.0727	0.1759	61.7275	102.7003	0.2380	95.5118	220.6193	0.2233	9.4806	25.6226	0.2256
GA66	189.4585	271.7830	0.2202	175.7663	297.1203	0.2026	64.3041	98.6383	0.2437	138.9774	263.5087	0.2260	4.1505	18.3532	0.2244
GA67	40.3106	57.4588	0.2749	8.7284	20.2411	0.2424	11.4095	15.3948	0.2884	10.0162	15.3772	0.2759	0.2301	0.6492	0.2630
GA68	23.6913	33.3280	0.2617	3.1709	7.2391	0.2455	6.1644	8.5723	0.2810	3.5042	5.5698	0.2669	0.1626	0.4265	0.2738
GA69	19.2834	88.2328	0.2331	96.7639	261.1628	0.2167	6.4505	43.8271	0.2558	7.8510	55.7291	0.2356	1.4495	9.4642	0.2284
GA70	101.0554	184.4279	0.2404	23.5889	164.0800	0.2140	26.4141	56.1690	0.2472	39.1324	120.7972	0.2294	1.9981	5.2349	0.2479
GA71	61.1253	125.4477	0.2395	49.0089	205.3067	0.2106	30.7175	58.3961	0.2532	24.2016	81.6982	0.2249	1.2161	9.9307	0.2254
GA72	112.7511	196.1082	0.2394	101.2493	197.3182	0.2130	33.8906	63.6637	0.2357	73.0129	148.1801	0.2319	2.5742	7.9899	0.2289

Appendix B-2 Experiment 2 Result

GA MODELS	B1			B2			B3			B4			B5		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA1	15.5523	19.4168	0.1838	0.5418	6.7351	0.1504	0.0000	0.0009	0.1482	429.2099	1527.8535	0.1715	0.2048	1.3603	0.1425
GA2	2.6836	4.0422	0.1501	0.1037	0.5271	0.1212	0.0000	0.0002	0.1403	16.3473	91.0444	0.1482	0.0169	0.1012	0.1388
GA3	16.5274	20.0403	0.1708	1.9545	22.2935	0.1244	0.0002	0.0143	0.1340	68.4474	4496.7967	0.1378	0.0516	4.0252	0.1344
GA4	3.0475	10.8079	0.1507	0.0004	3.9172	0.1269	0.0000	0.0049	0.1343	5.8158	988.3523	0.1335	0.0071	3.0682	0.1186
GA5	13.8920	19.8461	0.1594	0.2614	32.2527	0.1210	0.0000	0.0264	0.1255	413.7865	6272.0960	0.1408	0.3663	9.0771	0.1204
GA6	4.8636	12.4412	0.1420	0.2041	8.4113	0.1218	0.0000	0.0034	0.1338	18.4461	731.2047	0.1387	0.0354	5.6185	0.1194
GA7	18.2609	19.9792	0.1390	1.1491	9.6430	0.1309	0.0000	0.0006	0.1394	274.5173	1189.8539	0.1502	0.0526	1.6009	0.1187
GA8	2.7655	3.8756	0.1387	0.1069	0.4583	0.1320	0.0000	0.0001	0.1429	7.1793	90.0048	0.1500	0.0190	0.1064	0.1236
GA9	14.3952	19.6029	0.1318	0.3819	16.4068	0.1182	0.0001	0.0084	0.1297	28.9393	3431.3088	0.1337	0.0277	2.9336	0.1127
GA10	1.4157	8.5658	0.1296	0.0034	7.0557	0.1329	0.0000	0.0021	0.1276	11.9919	900.7702	0.1388	0.0122	2.2588	0.1206
GA11	13.2809	19.9407	0.1313	0.2856	28.6246	0.1265	0.0007	0.0096	0.1349	519.9911	5411.2422	0.1399	0.2942	5.8841	0.1250
GA12	4.0581	9.9840	0.1437	0.2990	6.8331	0.1206	0.0000	0.0014	0.1362	26.3455	1057.7727	0.1446	0.4386	4.6842	0.1205
GA13	16.1657	19.5280	0.1460	2.2688	7.9782	0.1342	0.0000	0.0014	0.1442	263.2814	1092.0547	0.1516	0.2920	1.3736	0.1208
GA14	2.4417	3.3935	0.1418	0.1034	0.5129	0.1363	0.0000	0.0002	0.1363	22.1046	77.8632	0.1414	0.0231	0.0891	0.1281
GA15	12.7126	19.4514	0.1366	0.0556	15.7385	0.1294	0.0002	0.0119	0.1348	161.1460	2201.0054	0.1517	0.0020	2.2136	0.1143
GA16	0.7019	6.7145	0.1341	0.0615	4.6818	0.1177	0.0000	0.0015	0.1369	6.3323	463.6458	0.1429	0.0263	1.2988	0.1213
GA17	14.4410	19.9444	0.1381	0.7947	19.8721	0.1274	0.0002	0.0083	0.1366	153.2201	3344.5563	0.1458	0.2219	2.5181	0.1149
GA18	3.9712	7.9597	0.1310	0.0158	2.9037	0.1302	0.0000	0.0012	0.1353	5.9028	660.7909	0.1448	0.0884	2.5383	0.1145
GA19	18.5847	20.1134	0.1408	112.4558	286.4062	0.1290	0.0334	0.6792	0.1246	26201.4110	48823.5833	0.1426	17.1800	53.5319	0.1121
GA20	2.8586	4.1361	0.1298	0.1851	0.7234	0.1144	0.0000	0.0002	0.1300	26.2767	96.7598	0.1325	0.0160	0.1214	0.1099
GA21	14.7290	20.1066	0.1264	139.6072	388.6211	0.1195	0.0298	1.0944	0.1257	30714.5992	63909.3766	0.1345	15.7601	69.8073	0.1033
GA22	4.5639	10.8526	0.1172	0.0001	5.6884	0.1172	0.0000	0.0016	0.1186	1.4942	831.4160	0.1334	0.0256	1.8148	0.0990
GA23	18.7474	20.4728	0.1209	133.2893	392.1718	0.1085	0.1465	1.4215	0.1314	23279.5077	65368.1285	0.1321	15.6445	67.1186	0.1044
GA24	6.8396	11.8473	0.1199	0.0055	4.6098	0.1249	0.0000	0.0010	0.1287	1.5251	908.0094	0.1224	0.1797	2.7355	0.1054
GA25	17.8336	20.1732	0.1290	108.6815	299.4679	0.1351	0.0612	0.5554	0.1404	18677.8513	44081.8996	0.1481	19.3119	50.4984	0.1097
GA26	2.2423	3.7816	0.1369	0.0781	0.4735	0.1225	0.0000	0.0002	0.1333	23.3016	115.8086	0.1469	0.0172	0.1127	0.1115
GA27	17.6956	20.4380	0.1237	92.0642	407.5363	0.1246	0.0486	1.0687	0.1312	13794.5455	64290.1407	0.1351	31.6339	69.7107	0.1027

GA MODELS	B1			B2			B3			B4			B5		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA29	17.6495	20.5151	0.1237	35.8150	437.4024	0.1171	0.1225	1.3452	0.1588	10457.8503	71656.0041	0.1381	26.6706	78.1976	0.1128
GA30	2.5716	9.8091	0.1498	0.0142	4.9320	0.1191	0.0000	0.0018	0.1565	13.3529	535.5890	0.1309	0.1863	2.4077	0.1116
GA31	18.3061	20.2577	0.1749	80.0341	244.6825	0.1401	0.0322	0.5177	0.1826	17619.9487	43901.1295	0.1515	27.5959	48.3986	0.1187
GA32	2.3078	3.4967	0.1722	0.1786	0.4848	0.1359	0.0000	0.0003	0.1717	9.9327	100.4696	0.1449	0.0159	0.1016	0.1461
GA33	16.8673	20.3326	0.1558	88.0035	345.3481	0.1688	0.0686	1.0332	0.1656	17661.2931	60003.0363	0.1333	21.5153	62.1482	0.1398
GA34	0.0793	6.9261	0.1442	0.0003	3.1961	0.1745	0.0000	0.0008	0.1689	1.5744	280.3266	0.1344	0.0070	0.9928	0.1398
GA35	18.8150	20.5867	0.1633	49.6811	380.4579	0.1623	0.0562	1.1722	0.1670	10664.2965	59119.6801	0.1353	8.5903	59.4068	0.1353
GA36	2.6142	7.8083	0.1562	0.0648	3.2569	0.1642	0.0000	0.0008	0.1599	12.9084	373.4523	0.1339	0.0142	1.3814	0.1393
GA37	4.9084	6.8053	0.1733	1.0452	3.2983	0.1576	0.0000	0.0011	0.1742	67.7829	493.1312	0.1367	0.1134	0.8396	0.1452
GA38	2.6102	3.7975	0.1805	0.0754	0.4513	0.1535	0.0000	0.0004	0.1833	24.0345	99.9572	0.1390	0.0330	0.1028	0.1414
GA39	0.3973	6.0973	0.1605	0.0695	19.3016	0.1571	0.0000	0.0092	0.1659	13.9999	3085.6703	0.1311	0.0003	1.9060	0.1390
GA40	5.3702	11.8399	0.1618	0.4658	6.9668	0.1563	0.0000	0.0022	0.1599	0.0084	492.3022	0.1347	0.1536	4.0392	0.1718
GA41	5.6908	10.6332	0.1676	0.2852	20.8743	0.1585	0.0000	0.0152	0.1639	80.5005	3576.9206	0.1363	0.0470	4.0605	0.1493
GA42	7.9101	13.6000	0.1687	0.0006	4.7967	0.1636	0.0000	0.0029	0.1634	11.9521	720.5978	0.1301	0.4215	5.7227	0.1380
GA43	4.6556	6.8000	0.1711	0.6650	2.5723	0.1628	0.0000	0.0011	0.1720	171.2964	450.7906	0.1483	0.2442	0.6235	0.1446
GA44	2.2888	3.5363	0.1701	0.0877	0.4525	0.1648	0.0000	0.0003	0.1842	13.1047	73.0240	0.1499	0.0131	0.0849	0.1469
GA45	0.1657	5.8097	0.1614	0.1615	15.3836	0.1561	0.0000	0.0107	0.1658	37.4262	2419.4816	0.1425	0.0009	1.2017	0.1267
GA46	2.1636	9.9782	0.1587	0.0012	3.6381	0.1565	0.0000	0.0018	0.1612	24.2666	926.8241	0.1470	0.0030	3.7485	0.1368
GA47	4.0714	8.8721	0.1679	0.8249	13.5396	0.1511	0.0001	0.0060	0.1609	74.5211	3215.1200	0.1479	0.0548	1.9859	0.1395
GA48	5.5388	12.3260	0.1523	0.2896	4.2780	0.1576	0.0001	0.0031	0.1648	37.4022	1155.7598	0.1774	0.3480	3.7422	0.1397
GA49	3.8495	6.4438	0.1752	0.9427	2.8151	0.1689	0.0000	0.0015	0.1776	73.0671	412.0864	0.1909	0.1903	0.5377	0.1509
GA50	2.2286	3.5992	0.1709	0.1286	0.4781	0.1636	0.0000	0.0003	0.1785	4.2896	63.6214	0.1897	0.0093	0.0739	0.1414
GA51	0.6435	5.4132	0.1678	0.0177	11.5517	0.1541	0.0000	0.0052	0.1666	4.4165	1650.0953	0.1790	0.0008	0.5394	0.1334
GA52	2.2093	8.8430	0.1685	0.0397	3.6756	0.1573	0.0000	0.0005	0.1708	3.4530	697.0840	0.1813	0.0212	1.3715	0.1327
GA53	0.1752	6.7146	0.1616	0.4162	17.1846	0.1598	0.0000	0.0031	0.1488	16.5607	2079.4991	0.1805	0.0421	1.1980	0.1404
GA54	5.7093	10.6164	0.1757	0.0002	2.6726	0.1584	0.0000	0.0003	0.1354	7.5245	551.3914	0.1819	0.0521	1.9527	0.1388
GA55	2.6472	4.1465	0.1769	0.1528	0.9254	0.1714	0.0000	0.0008	0.1370	35.0886	117.1208	0.1971	0.0411	0.1614	0.1579
GA56	1.9121	3.3391	0.1797	0.1277	0.5077	0.1719	0.0000	0.0001	0.1321	15.6807	68.0454	0.2003	0.0126	0.0681	0.1585

GA MODELS	B1			B2			B3			B4			B5		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA57	0.1000	5.5059	0.1719	0.3076	24.3665	0.1643	0.0000	0.0096	0.1303	162.8041	4016.0469	0.1881	0.0006	1.0107	0.1460
GA58	8.2952	14.2209	0.1701	0.3554	6.2731	0.1581	0.0000	0.0025	0.1327	4.3471	1211.7478	0.1921	1.0395	7.3419	0.1286
GA59	1.0819	9.5139	0.1694	0.5795	22.9388	0.1609	0.0001	0.0180	0.1306	93.6014	4407.6105	0.1876	0.1603	2.3893	0.1444
GA60	8.1100	14.4115	0.1583	0.2824	7.1248	0.1656	0.0000	0.0011	0.1208	0.1724	1033.6977	0.1912	0.6384	10.0976	0.1497
GA61	2.4069	3.9084	0.1810	0.1145	0.6022	0.1741	0.0000	0.0005	0.1405	36.8536	103.9583	0.2008	0.0504	0.1442	0.1587
GA62	2.1536	3.3366	0.1874	0.0874	0.3944	0.1743	0.0000	0.0003	0.1437	7.9021	64.7421	0.2078	0.0177	0.0763	0.1583
GA63	0.2295	5.2662	0.1681	0.4814	18.1383	0.1639	0.0000	0.0135	0.1373	597.9264	3353.9659	0.1864	0.0009	0.9822	0.1454
GA64	6.7628	13.4800	0.1714	0.0274	6.0389	0.1645	0.0000	0.0026	0.1239	0.0258	1138.0563	0.1884	0.0617	4.5684	0.1465
GA65	1.1826	7.7993	0.1733	0.5564	21.1758	0.1649	0.0000	0.0142	0.1368	241.3449	3372.7052	0.1931	0.0142	1.2766	0.1341
GA66	7.2398	12.8703	0.1657	0.2625	9.7940	0.1668	0.0000	0.0039	0.1345	0.0487	1128.9838	0.1868	0.6944	5.5830	0.1389
GA67	3.0014	4.1793	0.1864	0.1636	0.8824	0.1785	0.0000	0.0005	0.1449	24.1586	134.4580	0.2020	0.0266	0.1059	0.1483
GA68	1.0453	3.3836	0.1860	0.0552	0.3100	0.1750	0.0000	0.0001	0.1370	5.4676	58.9851	0.2018	0.0164	0.0649	0.1196
GA69	0.0653	4.5650	0.1802	0.1592	11.5458	0.1709	0.0000	0.0055	0.1383	84.0872	2304.9567	0.1907	0.0001	0.4002	0.1182
GA70	6.8467	11.4192	0.1773	0.0055	4.4346	0.1672	0.0000	0.0019	0.1359	1.8226	686.8270	0.1931	0.0000	2.4820	0.1261
GA71	0.3763	5.9616	0.1759	0.5587	17.0729	0.1702	0.0000	0.0038	0.1399	2.3694	1788.4585	0.1898	0.0205	1.1812	0.1199
GA72	4.9750	11.7399	0.1918	0.0201	6.2497	0.1679	0.0000	0.0010	0.1348	0.4730	963.2771	0.1955	0.1567	4.7066	0.1199

GA MODELS	B6			B7			B8			B9			B10		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA1	19.6164	43.3538	0.1624	1.9928	8.4045	0.1414	3.3336	10.3652	0.1489	1.9647	6.6476	0.1453	0.0020	0.1292	0.1508
GA2	2.2996	6.1221	0.1249	0.0650	0.2525	0.1254	0.8150	1.4626	0.1355	1.1288	1.4422	0.1234	0.0064	0.0906	0.1388
GA3	5.9099	45.6615	0.1192	0.5200	43.5302	0.1175	0.5006	17.1087	0.1323	1.0159	20.1802	0.1197	0.0345	0.2612	0.1270
GA4	3.4191	21.2791	0.1180	3.8573	56.5118	0.1134	1.6279	12.0267	0.1295	1.0509	12.2433	0.1222	0.0181	0.2518	0.1227
GA5	12.1871	62.9706	0.1180	3.7962	52.7564	0.1161	7.0847	22.7220	0.1250	2.7586	24.9607	0.1220	0.0523	0.5992	0.1323
GA6	9.9098	35.6578	0.1233	20.4786	54.5248	0.1137	6.5067	17.2225	0.1324	2.8193	18.5231	0.1187	0.0227	0.3689	0.1299
GA7	16.1360	34.5331	0.1266	2.5832	7.0536	0.1189	3.1301	7.9919	0.1413	2.3994	6.1129	0.1364	0.0231	0.1083	0.1352
GA8	1.8863	6.0983	0.1302	0.0587	0.3018	0.1232	0.7158	1.3037	0.1410	1.0915	1.3131	0.1387	0.0149	0.0780	0.1332
GA9	8.4770	38.6022	0.1197	0.6614	33.3607	0.1180	2.1164	14.5066	0.1245	2.2199	10.9350	0.1235	0.0161	0.2736	0.1344
GA10	1.7419	17.9105	0.1162	12.5253	45.8550	0.1184	1.2815	7.8380	0.1292	1.0330	6.5340	0.1298	0.0346	0.2454	0.1334
GA11	14.4014	54.9153	0.1173	5.9420	49.6462	0.1156	2.1237	18.1949	0.1316	1.5937	16.6998	0.1331	0.0125	0.4538	0.1323
GA12	8.3637	29.3282	0.1183	12.3901	44.0276	0.1162	5.4243	13.9441	0.1304	2.2459	16.4634	0.1209	0.0182	0.2901	0.1262
GA13	14.6499	36.7583	0.1261	0.9662	4.9659	0.1248	3.0949	7.5685	0.1404	1.7259	5.5562	0.1353	0.0209	0.1090	0.1450
GA14	1.5021	5.0830	0.1245	0.1430	0.3406	0.1429	0.7829	1.3468	0.1353	1.0389	1.3126	0.1350	0.0150	0.0556	0.1397
GA15	1.0300	32.3837	0.1193	0.6353	33.0890	0.1173	0.3926	11.0033	0.1323	1.3040	10.0313	0.1392	0.0187	0.3824	0.1346
GA16	0.5942	10.8142	0.1186	1.8730	29.2752	0.1169	0.9303	6.6322	0.1415	1.0226	4.6301	0.1292	0.0179	0.1764	0.1358
GA17	11.0291	44.0449	0.1239	1.3385	46.0980	0.1178	3.2051	13.1163	0.1347	2.0431	16.2061	0.1334	0.0227	0.2458	0.1282
GA18	4.9616	20.2987	0.1207	3.3778	35.5780	0.1186	3.9738	9.4755	0.1365	1.1841	11.7102	0.1286	0.0140	0.1839	0.1327
GA19	90.1771	134.5138	0.1178	52.7870	2104.3833	0.1134	32.7756	106.6826	0.1230	100.4366	168.7575	0.1281	1.1933	11.0232	0.1268
GA20	2.4056	5.7347	0.1224	0.1345	0.6455	0.1189	0.6918	1.6538	0.1309	1.1493	1.5576	0.1292	0.0044	0.0643	0.1303
GA21	108.6307	168.2898	0.1150	74.7940	25230.7069	0.1070	26.5857	206.8303	0.1252	106.3528	238.3269	0.1235	6.5641	26.0017	0.1146
GA22	0.1627	19.3142	0.1128	0.4379	16.2562	0.1111	1.0764	9.9003	0.1215	1.1842	7.9772	0.1299	0.0676	0.2362	0.1226
GA23	102.8297	183.5443	0.1178	150.2277	23960.9031	0.1138	51.4537	209.3157	0.1202	46.9489	232.4450	0.1184	1.2660	24.6891	0.1250
GA24	8.3598	30.6401	0.1188	2.6737	29.0434	0.1052	1.8043	13.6797	0.1205	2.4444	14.0275	0.1241	0.0480	0.2490	0.1211
GA25	103.1158	141.3639	0.1507	47.8430	5884.6796	0.1187	24.5599	113.7056	0.1308	65.6877	162.8292	0.1341	3.8268	12.3596	0.1256
GA26	1.9901	5.4949	0.1525	0.1289	0.4339	0.1123	0.7197	1.4580	0.1234	1.1388	1.4100	0.1259	0.0191	0.0526	0.1343
GA27	41.3377	170.6623	0.1456	50.1359	38702.8986	0.1129	71.9618	266.8832	0.1265	89.5299	258.4727	0.1441	3.7548	17.0493	0.1271
GA28	0.0704	12.8110	0.1449	0.0133	14.1933	0.1117	0.3884	6.1670	0.1283	1.0192	4.6433	0.1531	0.0213	0.1223	0.1303

GA MODELS	B6			B7			B8			B9			B10		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA29	101.6499	167.6603	0.1442	90.9921	53101.5432	0.1081	51.1057	293.3528	0.1308	81.5982	265.3411	0.1548	3.7293	20.4234	0.1219
GA30	6.3286	23.7376	0.1453	4.9405	18.5244	0.1060	4.8366	11.2511	0.1186	1.2620	10.5189	0.1503	0.0138	0.1432	0.1316
GA31	88.5476	137.6072	0.1616	57.0537	1710.3897	0.1172	43.4781	122.7541	0.1399	77.3764	179.8467	0.1712	2.7589	12.7527	0.1416
GA32	2.1811	5.6425	0.1602	0.0918	0.5129	0.1199	0.6934	1.3754	0.1364	1.1111	1.3049	0.1659	0.0140	0.0465	0.1364
GA33	103.2548	163.6203	0.1535	40.8131	24941.7939	0.1166	21.0251	259.1206	0.1282	80.2545	209.9964	0.1550	2.5083	17.8705	0.1189
GA34	0.0627	11.4102	0.1424	0.1040	4.9618	0.1180	0.3245	5.0768	0.1211	1.0463	2.8768	0.1518	0.0197	0.0911	0.1405
GA35	83.0823	161.9944	0.1501	25.8356	28962.0250	0.1206	38.3657	205.9343	0.1617	157.2123	274.0716	0.1583	3.7911	22.7244	0.1612
GA36	0.0678	15.9379	0.1400	1.6513	7.5933	0.1120	1.5018	7.1063	0.1583	1.3316	5.9930	0.1537	0.0054	0.1345	0.1630
GA37	6.8419	13.8970	0.1605	0.7944	3.6708	0.1219	2.0495	3.8939	0.1702	1.6644	3.4836	0.1587	0.0387	0.1556	0.1721
GA38	2.1828	5.8633	0.1631	0.0905	0.4262	0.1233	0.5631	1.4261	0.1678	1.0947	1.3287	0.1666	0.0230	0.0702	0.1730
GA39	0.0723	15.8433	0.1491	0.5822	35.7976	0.1173	0.4483	6.9948	0.1610	1.0001	5.2508	0.1534	0.0677	0.4203	0.1581
GA40	0.8017	29.7862	0.1581	3.6358	26.3257	0.1372	0.8069	14.2896	0.1623	1.0083	14.2137	0.1583	0.0195	0.2704	0.1597
GA41	6.1404	27.8342	0.1453	1.9454	49.9270	0.1479	3.0737	14.8776	0.1622	1.0543	12.7243	0.1595	0.0523	0.5769	0.1616
GA42	7.6816	39.6384	0.1401	0.8640	31.2277	0.1457	3.6147	14.9238	0.1568	2.9315	22.3134	0.1541	0.0361	0.4800	0.1596
GA43	8.6721	13.9088	0.1624	1.1490	4.3126	0.1607	1.8314	3.6029	0.1714	1.8179	2.7812	0.1645	0.0424	0.1790	0.1693
GA44	1.7930	5.1692	0.1588	0.0698	0.3686	0.1528	0.9206	1.5605	0.1763	1.0646	1.3006	0.1596	0.0211	0.0708	0.1718
GA45	0.1573	8.5696	0.1538	0.6078	24.3316	0.1481	0.3835	6.2015	0.1628	1.0016	3.4671	0.1585	0.0132	0.3798	0.1595
GA46	5.1321	24.2510	0.1491	1.3100	20.0274	0.1460	0.6035	11.7044	0.1581	1.1042	11.3486	0.1476	0.0079	0.2287	0.1610
GA47	4.8274	20.5163	0.1225	0.4541	34.3693	0.1479	1.3895	9.3683	0.1595	1.0671	7.4671	0.1624	0.0510	0.3609	0.1595
GA48	6.6926	30.1436	0.1477	1.7006	23.6192	0.1475	3.0173	11.7063	0.1584	1.6966	14.7660	0.1526	0.0026	0.2320	0.1658
GA49	6.6416	13.0966	0.1628	0.8121	3.8752	0.1663	1.6907	3.8386	0.1723	1.3279	3.0536	0.1731	0.0400	0.1592	0.1829
GA50	3.1333	5.5480	0.1643	0.0633	0.3154	0.1591	0.4078	1.2623	0.1744	1.0522	1.3030	0.1618	0.0145	0.0523	0.1725
GA51	0.1261	10.1879	0.1553	0.0004	17.5020	0.1518	0.0351	5.2004	0.1618	1.0048	2.3064	0.1522	0.0387	0.2185	0.1676
GA52	1.8191	19.5509	0.1536	0.5188	13.7415	0.1516	0.3215	7.6209	0.1653	1.0771	8.2379	0.1585	0.0074	0.1115	0.1653
GA53	1.1223	13.4861	0.1462	0.9757	31.9823	0.1452	0.8968	8.5681	0.1587	1.0026	5.3118	0.1562	0.0259	0.3585	0.1571
GA54	9.7469	24.4945	0.1588	0.2502	13.6874	0.1503	1.3890	8.6280	0.1469	1.0879	10.4821	0.1523	0.0057	0.1386	0.1630
GA55	4.0849	7.3306	0.1646	0.1745	0.5972	0.1933	0.6200	1.6081	0.1730	1.1088	1.5002	0.1704	0.0442	0.1310	0.1844
GA56	2.6911	5.0348	0.1677	0.0347	0.2526	0.1614	0.8524	1.3391	0.1837	1.0834	1.3276	0.1758	0.0115	0.0820	0.1807

GA MODELS	B6			B7			B8			B9			B10		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA57	0.2831	14.7731	0.1607	0.9320	24.0117	0.1639	0.9913	6.2440	0.1704	1.0001	4.0499	0.1669	0.0529	0.3221	0.1742
GA58	3.6787	43.4850	0.1639	0.4854	37.9376	0.1587	2.6154	15.8897	0.1643	2.7653	21.8361	0.1622	0.0103	0.2886	0.1730
GA59	5.9646	26.0416	0.1538	0.6552	51.0885	0.1596	2.7689	12.7298	0.1675	1.0546	12.4201	0.1535	0.0625	0.6472	0.1723
GA60	14.0171	49.9949	0.1566	4.1232	42.4406	0.1594	9.5764	21.6627	0.1555	2.9964	31.3793	0.1867	0.0407	0.4249	0.1720
GA61	3.8984	7.2253	0.1715	0.2088	0.6841	0.1631	0.7501	1.7181	0.1692	1.0579	1.3738	0.1719	0.0256	0.1092	0.1814
GA62	3.0553	5.0666	0.1675	0.0605	0.3092	0.1581	0.7265	1.3447	0.1708	1.0248	1.2917	0.1719	0.0100	0.0615	0.1826
GA63	0.0133	8.9891	0.1592	0.0154	23.5708	0.1609	0.0562	6.7497	0.1720	1.0018	2.9050	0.1649	0.0178	0.3478	0.1726
GA64	9.9987	37.5537	0.1606	0.2470	27.4545	0.1572	6.2910	13.0155	0.1650	1.5485	15.1404	0.1614	0.0345	0.3374	0.1741
GA65	1.6717	16.7112	0.1645	0.2812	37.8533	0.1609	2.3239	11.0770	0.1643	1.0301	5.9213	0.1634	0.0250	0.4281	0.1698
GA66	11.9209	36.9454	0.1570	3.5330	32.0778	0.1574	5.5697	17.0102	0.1675	1.7948	23.1829	0.1630	0.0298	0.3589	0.1711
GA67	3.9446	7.0912	0.1766	0.1210	0.5551	0.1743	0.6580	1.6961	0.1810	1.1507	1.6224	0.1616	0.0186	0.0888	0.1840
GA68	1.7885	5.3330	0.1841	0.0571	0.3110	0.1695	0.6330	1.2000	0.1705	1.0703	1.2490	0.1755	0.0022	0.0655	0.1855
GA69	0.3230	8.2575	0.1615	0.0463	12.4125	0.1627	0.0378	3.7901	0.1736	1.0013	3.0345	0.1665	0.0138	0.2652	0.1773
GA70	3.1523	25.6608	0.1682	0.6976	20.7757	0.1623	3.4684	9.3268	0.1631	1.0391	12.9293	0.1603	0.0123	0.1285	0.1771
GA71	0.1424	10.7758	0.1656	0.2098	22.2239	0.1628	0.1169	5.3943	0.1687	1.0050	3.6586	0.1697	0.0311	0.2811	0.1667
GA72	13.2725	32.2521	0.1642	0.6749	27.2373	0.1634	2.5949	11.9999	0.1681	4.0048	17.9865	0.1639	0.0184	0.2007	0.1760

Appendix B-3 Experiment 3 Result

GA MODELS	B1			B2			B3			B4			B5		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA01	20.0254	20.5762	0.7856	448.4390	760.5721	0.7139	0.0000	0.0001	0.8799	55039.6853	113616.3828	1.3876	43.9630	72.5651	0.6974
GA02	1.7527	2.5396	0.7508	0.5699	1.2321	0.7208	0.0000	0.0000	0.8260	67.8177	183.2553	1.3582	0.0436	0.0854	0.6880
GA03	19.4643	20.6343	0.6332	111.5891	538.2100	0.6202	0.0002	0.0061	0.6877	15946.9415	72658.4538	1.0142	2.5586	36.3963	0.5786
GA04	9.4094	16.4950	0.6325	1.4260	33.2143	0.6099	0.0000	0.0013	0.7039	417.2719	5790.3505	1.2058	0.0925	28.6672	0.5944
GA05	20.0848	20.9713	0.6331	570.1205	1263.9116	0.6578	0.0023	0.0691	0.8374	53729.6381	210622.1353	1.1901	26.5379	82.5134	0.6051
GA06	15.9968	17.8853	0.6575	3.1122	48.2872	0.7596	0.0000	0.0029	0.8622	681.0797	7238.8178	1.1904	16.4365	65.4718	0.6898
GA07	20.1530	20.6130	0.9282	171.9579	709.7360	0.9150	0.0000	0.0000	1.0775	35748.6820	91711.8925	1.6215	24.5311	65.6148	0.8899
GA08	1.2687	2.4246	0.9662	0.4911	1.0097	0.9194	0.0000	0.0000	1.0825	95.0829	182.8552	1.6200	0.0348	0.0820	0.8868
GA09	18.9950	20.6637	0.8138	111.4934	577.7321	0.7869	0.0002	0.0084	0.8805	12328.5768	68970.2473	1.1909	7.9117	38.2023	0.7514
GA10	6.6214	14.4542	0.7683	2.2642	40.5036	0.7828	0.0000	0.0015	0.8724	41.2956	4800.1064	1.1791	0.3448	15.6788	0.7359
GA11	20.2180	20.8801	0.6877	226.9861	907.8505	0.8059	0.0008	0.0394	0.8564	26991.4999	146556.0943	1.1899	14.3833	65.8936	0.7403
GA12	13.0693	16.4443	0.6449	1.6022	35.9538	0.7899	0.0000	0.0051	0.8497	809.9160	7295.5141	1.1889	5.6321	46.3700	0.7503
GA13	19.8550	20.5920	0.8036	181.2585	530.0488	0.9691	0.0000	0.0000	1.0526	37658.2806	75738.1698	1.6529	21.8651	57.7200	0.8768
GA14	1.6968	2.2406	0.7772	0.4250	0.7741	0.9374	0.0000	0.0000	1.0546	59.9637	148.4613	1.6346	0.0278	0.0530	0.8604
GA15	18.9925	20.7042	0.6455	36.0952	476.8640	0.8013	0.0000	0.0053	0.8675	6147.2410	68013.7721	1.2229	1.9563	23.2413	0.7593
GA16	4.3943	11.4330	0.6932	0.4139	20.3399	0.7947	0.0000	0.0006	0.8815	97.2020	3788.8033	1.2125	0.0051	5.3805	0.7464
GA17	19.4782	20.7463	0.7680	141.4252	584.5252	0.8075	0.0008	0.0116	0.8861	11101.7887	71911.0323	1.2188	4.8826	43.8044	0.7515
GA18	8.1270	13.0322	0.8531	1.2845	17.0191	0.7996	0.0000	0.0008	0.8753	305.9946	2839.2988	1.1944	4.8218	18.2388	0.7135
GA19	20.2800	20.7056	0.9275	2439.7953	3056.9106	0.8497	0.1385	1.2406	0.9685	341379.8810	482235.4323	1.6614	111.7066	190.2178	0.8005
GA20	1.8079	2.5242	0.9226	0.5586	1.2075	0.8427	0.0000	0.0000	0.9752	115.3835	207.6938	1.5688	0.0416	0.0905	0.7784
GA21	19.8411	20.8511	0.7628	1751.2743	3815.0434	0.7352	0.3551	2.2388	0.8088	214058.0915	612247.9412	1.1417	120.4684	225.0450	0.6845
GA22	12.5281	16.8951	0.7633	0.4302	33.8025	0.7200	0.0000	0.0005	0.7968	26.0345	6050.8270	1.1432	0.2529	24.7572	0.6635
GA23	20.3785	20.9993	0.7745	1884.0675	3983.8527	0.7305	0.4092	2.5472	0.8106	420594.1033	665930.5717	1.1589	142.4437	237.9201	0.6736
GA24	14.9402	17.6601	0.7530	4.4967	53.0825	0.7286	0.0001	0.0028	0.8179	172.5467	5974.8864	1.1426	25.8223	52.5139	0.6700
GA25	19.4260	20.6037	0.9177	1836.0183	2937.7024	0.8553	0.1083	1.1265	1.0662	272249.9604	493644.6704	1.5766	123.8449	203.6492	0.7943
GA26	1.9512	2.5589	0.9192	0.5902	1.2052	0.8398	0.0000	0.0000	0.9779	75.2122	168.3024	1.5691	0.0508	0.0943	0.7895
GA27	17.5131	20.6594	0.7664	1950.3748	4006.1626	0.7389	0.1735	1.8768	0.8010	275740.6766	608362.4964	1.1509	112.1625	242.7027	0.6786
GA28	10.0601	15.3310	0.7684	1.9035	40.4146	0.7304	0.0000	0.0011	0.7993	111.1942	5526.6032	1.1410	0.0474	13.8997	0.6802

GA MODELS	B1			B2			B3			B4			B5		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA29	20.4370	20.9378	0.7711	1558.5315	3852.2252	0.7281	0.3624	2.4341	0.8117	375814.6016	603492.8499	1.1404	167.9647	257.5388	0.6812
GA30	12.8995	16.4665	0.7601	4.0009	38.1514	0.7268	0.0000	0.0020	0.8087	507.3431	6483.3663	1.1439	7.8559	40.2510	0.6790
GA31	19.9885	20.6627	0.9595	2407.3545	3007.8731	0.9774	0.2707	1.1602	1.0060	302629.7327	438652.2053	1.6149	140.6350	197.0599	0.8163
GA32	1.3252	2.2130	0.9535	0.2886	0.8759	0.8896	0.0000	0.0000	1.0140	39.9669	144.7205	1.5879	0.0208	0.0576	0.8148
GA33	19.7344	20.8164	0.8079	2638.2666	3712.9937	0.7815	0.4668	2.1388	0.8408	417661.0763	668625.4309	1.2476	100.0052	231.4265	0.7118
GA34	3.5907	10.4400	0.7937	0.4217	14.3356	0.7569	0.0000	0.0004	0.8205	146.2028	2384.8593	1.2187	0.0043	2.8953	0.7075
GA35	20.1376	20.9142	0.7968	2103.2634	3753.2520	0.7614	0.6334	2.5424	0.8314	330993.6007	644218.8937	1.1748	114.7081	248.8788	0.7192
GA36	10.9530	13.2258	0.8068	0.2609	12.3867	0.7462	0.0000	0.0006	0.8276	91.5145	3270.6974	1.1758	1.9508	12.4215	0.7082
GA37	11.5393	13.5999	0.9785	139.0193	221.1957	0.8612	0.0000	0.0003	0.9782	20900.6305	41596.0982	1.5923	9.9177	20.2241	0.8023
GA38	1.1142	2.0961	0.9240	0.3311	0.8328	0.8436	0.0000	0.0000	0.9871	74.9477	149.7131	1.5752	0.0191	0.0603	0.7989
GA39	0.8445	4.8442	0.7676	4.4556	117.9876	0.7326	0.0000	0.0038	0.8095	3290.0969	16860.9957	1.1512	0.0159	0.8369	0.6961
GA40	13.3844	17.4994	0.7683	0.0381	33.6872	0.7307	0.0000	0.0009	0.8085	6.5247	5871.8786	1.1611	1.8636	36.6614	0.6764
GA41	6.0700	13.5267	0.7548	58.0933	237.1268	0.7427	0.0000	0.0188	0.8004	11192.9219	40428.7161	1.1684	3.1800	26.8319	0.6846
GA42	17.0696	18.4208	0.7458	3.6371	37.5087	0.7350	0.0000	0.0020	0.8205	611.1888	8070.0193	1.1502	23.5310	64.4998	0.6873
GA43	11.1640	13.7007	0.9186	127.9969	229.4966	0.8722	0.0000	0.0004	0.9970	20607.5107	37586.7123	1.6000	12.5898	19.0684	0.8021
GA44	1.3677	2.1165	0.9095	0.3167	0.7225	0.8563	0.0000	0.0000	0.9829	54.1261	123.3689	1.5893	0.0266	0.0497	0.8016
GA45	0.1094	3.9988	0.7450	18.8404	110.5274	0.7294	0.0000	0.0178	0.8103	2284.9157	21550.6658	1.1504	0.0006	0.4650	0.6852
GA46	12.2019	17.6057	0.7716	0.1261	36.7838	0.7418	0.0000	0.0005	0.8312	18.1486	7556.4685	1.1765	0.2262	28.9301	0.6950
GA47	6.1046	12.0767	0.7724	39.8950	123.1215	0.7460	0.0000	0.0072	0.8705	8164.1564	27549.3686	1.1515	0.9298	12.4171	0.6735
GA48	13.1546	17.5331	0.7620	0.8380	58.0745	0.7493	0.0000	0.0015	0.8388	317.6074	8247.8809	1.1681	29.3912	58.5743	0.7009
GA49	10.6866	13.0008	0.9485	90.4873	187.1704	0.8896	0.0000	0.0003	1.0310	18765.0634	32714.0319	1.7131	8.2221	16.1300	0.8277
GA50	1.1145	2.0969	0.9249	0.2740	0.6014	0.8838	0.0000	0.0000	1.0208	34.5702	104.5816	1.6007	0.0196	0.0463	0.8332
GA51	0.0407	3.1260	0.7896	0.4235	56.9024	0.7664	0.0000	0.0026	0.8453	253.3847	10599.2960	1.1931	0.0033	0.2935	0.7007
GA52	9.9076	14.3553	0.7649	0.5654	17.0338	0.7578	0.0000	0.0004	0.8380	333.5621	4027.6550	1.1864	0.8936	13.9420	0.7075
GA53	3.0530	6.7051	0.8114	4.9339	59.4060	0.7717	0.0000	0.0080	0.8494	926.4970	11340.6524	1.1944	0.2863	2.5626	0.7201
GA54	12.4096	15.5395	0.7889	0.4256	24.2545	0.7672	0.0000	0.0015	0.8375	97.5440	4492.9114	1.1763	8.9804	26.0522	0.7157
GA55	3.4295	4.0198	0.9486	1.6135	4.5352	0.9701	0.0000	0.0000	1.0334	319.7218	784.1736	1.6206	0.1721	0.3779	0.8213
GA56	1.2451	1.9673	0.9355	0.1775	0.6086	0.8941	0.0000	0.0000	1.0202	51.3705	106.8429	1.6169	0.0196	0.0412	0.8277
GA57	0.0663	4.4721	0.7937	14.4239	188.1447	0.7870	0.0000	0.0037	0.8326	5930.1470	31957.0728	1.1943	0.0011	0.7082	0.7237

GA MODELS	B1			B2			B3			B4			B5		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA58	15.9498	18.7061	0.8113	1.8882	39.1229	0.7778	0.0000	0.0006	0.8563	92.3019	6855.6770	1.1894	7.2526	57.7536	0.7156
GA59	6.5705	12.9448	0.7868	81.7157	311.1738	0.7773	0.0002	0.0069	0.8459	13933.3884	51376.7188	1.1954	3.8709	16.1007	0.7387
GA60	17.2339	18.8973	0.8086	1.8665	60.8854	0.7824	0.0000	0.0017	0.8516	1003.5970	8591.6321	1.1981	27.2532	89.7903	0.7194
GA61	2.9749	3.8624	0.9950	1.7545	4.2630	0.8912	0.0000	0.0000	1.0255	369.3556	948.2379	1.6305	0.1096	0.3217	0.8366
GA62	1.2161	1.8428	0.9678	0.1673	0.6115	0.8969	0.0000	0.0000	1.0327	55.3819	97.9270	1.6090	0.0144	0.0358	0.8377
GA63	0.0085	3.0684	0.7953	12.0846	150.6593	0.7769	0.0000	0.0048	0.8567	1944.9044	20901.8758	1.3013	0.0019	0.9116	0.7125
GA64	16.9826	18.3066	0.7994	0.1409	41.3800	0.7911	0.0000	0.0044	0.7638	486.5380	7649.7080	1.1939	0.3693	35.1922	0.7273
GA65	7.4911	11.3985	0.8068	26.2740	139.7848	0.7727	0.0000	0.0095	0.6828	4180.2839	24187.4774	1.2056	0.5754	9.9377	0.7239
GA66	14.4606	18.2502	0.7937	8.0319	54.6216	0.7804	0.0000	0.0025	0.6960	588.7236	6885.6415	1.2043	17.2981	74.4319	0.7306
GA67	3.1108	4.0291	0.9723	2.1779	4.3147	0.9204	0.0000	0.0000	0.9074	280.0633	640.6739	1.6581	0.1406	0.3481	0.8589
GA68	1.1205	1.7918	0.9695	0.1649	0.5041	0.9389	0.0000	0.0000	1.0652	46.3297	99.7267	1.6497	0.0170	0.0342	0.8580
GA69	0.0212	3.3030	0.8261	1.9449	71.8910	0.7980	0.0000	0.0016	0.9353	178.2581	13026.3542	1.2388	0.0003	1.1879	0.7524
GA70	10.8369	15.2663	0.8264	0.2532	28.0236	0.8065	0.0000	0.0009	0.8962	447.7584	4747.9686	1.2175	1.0075	21.7898	0.7539
GA71	1.4808	6.1327	0.8287	3.3467	42.6930	0.8071	0.0000	0.0033	0.9062	743.5255	11109.9335	1.2344	0.0051	1.3842	0.7515
GA72	12.6337	16.6136	0.8231	0.5877	30.4034	0.8057	0.0000	0.0008	0.8975	90.5126	4893.7304	1.2408	12.0836	36.8730	0.7475

GA MODELS	B6			B7			B8			B9			B10		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA01	284.7689	374.4992	0.7381	51.8174	115.2411	0.7333	77.3258	97.6003	0.8126	129.2964	263.2606	0.8303	0.2877	0.9836	0.8029
GA02	4.1783	7.3690	0.7324	0.0561	0.1206	0.7071	1.2605	2.0806	0.7858	1.1968	1.3335	0.8070	0.0724	0.1633	0.7859
GA03	111.2650	274.9779	0.6163	104.6816	278.0256	0.6001	27.4550	79.8816	0.6606	32.0073	128.0457	0.6636	1.4710	9.6503	0.6471
GA04	15.9457	158.7239	0.6088	199.9800	360.8128	0.6068	16.6484	53.7706	0.6493	2.0639	88.0553	0.6630	0.3614	1.5391	0.6789
GA05	268.0345	376.4963	0.6123	244.9482	401.7363	0.5826	82.8989	133.0013	0.7955	82.9370	321.4896	0.6824	6.0637	22.6317	0.7491
GA06	103.8631	228.0398	0.6292	187.7130	432.8141	0.6019	63.5505	93.9544	0.8253	84.8577	206.4161	0.7177	1.4222	4.4012	0.8436
GA07	303.7335	373.5470	0.8371	32.5910	135.8321	0.8529	67.4426	96.2311	1.0182	86.4114	223.8507	1.0352	0.4058	0.9643	1.0119
GA08	5.2573	7.3991	0.9390	0.0682	0.1189	0.9090	1.2893	1.8635	0.9884	1.1206	1.2791	1.0402	0.0541	0.1441	1.0085
GA09	64.3089	271.2959	0.7762	128.3619	310.8833	0.7732	39.1088	84.4363	0.8361	20.8100	116.4733	0.8568	0.2577	5.6410	0.8389
GA10	8.4707	116.3340	0.7847	187.8210	345.2711	0.7646	2.4124	38.9125	0.8191	1.5002	57.2530	0.8620	0.2661	1.7781	0.8235
GA11	185.5328	333.2015	0.7761	222.5347	370.5564	0.7658	63.8875	118.8467	0.8276	86.6316	223.5303	0.8627	2.6888	17.3642	0.8192
GA12	113.4634	188.7254	0.7844	223.6753	367.7855	0.7524	48.7021	80.7000	0.7977	25.2856	134.6886	0.8519	1.4836	3.3159	0.8207
GA13	277.8400	359.3126	0.9629	40.7893	122.8457	0.9351	55.6388	95.5112	1.0091	44.5352	175.9179	1.0286	0.2333	0.6969	0.9965
GA14	3.5664	6.2790	0.9317	0.0512	0.1029	0.9340	1.2633	1.6614	0.9957	1.0820	1.2057	1.0204	0.0739	0.1178	0.9942
GA15	98.5905	242.6016	0.7857	44.8846	259.4716	0.7299	12.0909	76.5441	0.8444	13.3556	99.2563	0.8659	0.3045	3.1430	0.8586
GA16	11.8908	64.7617	0.7583	140.9418	275.9295	0.7415	7.3285	23.1415	0.8285	1.2212	33.2785	0.8636	0.1978	0.8169	0.8565
GA17	125.1118	273.5500	0.7834	94.7469	280.9750	0.7890	26.5158	74.8347	0.8525	17.8568	135.2243	0.8662	0.1726	3.9114	0.8435
GA18	41.2881	100.2099	0.7736	184.7315	289.8937	0.7528	15.7063	44.5795	0.8242	16.7919	57.8376	0.8665	0.2184	1.5432	0.8440
GA19	378.4553	477.9649	0.8334	423.2812	303799.6901	0.8272	97.1855	385.7294	0.9220	486.3221	672.4492	0.9467	51.0758	164.1850	0.9243
GA20	5.9407	8.8153	0.8383	0.2222	0.4507	0.8111	1.3591	2.1556	0.9059	1.1355	1.3141	0.9491	0.0976	0.1648	0.9180
GA21	390.1495	544.9426	0.7029	2194.9214	2791684.5448	0.7138	272.7326	802.5802	0.7787	278.0935	749.2643	0.7765	88.1522	228.0006	0.7740
GA22	18.7669	160.0424	0.7066	63.7618	189.6200	0.7022	8.5398	43.3373	0.7615	1.1586	68.0803	0.7833	0.4822	1.4928	0.7594
GA23	461.7894	562.0001	0.6969	702.8687	2942611.4474	0.7094	171.0172	746.2242	0.7737	630.6375	910.7332	0.7771	80.3044	228.5561	0.7704
GA24	144.4290	228.5387	0.6933	151.5544	277.2035	0.6934	47.5030	90.4608	0.7577	60.7357	173.3570	0.7769	0.1796	5.0010	0.7596
GA25	377.9587	463.3276	0.8452	421.7930	341907.5585	0.8390	145.3590	397.0653	0.9167	430.5243	680.8553	0.9465	55.0268	153.8403	0.9327
GA26	3.9740	7.7070	0.8390	0.1434	0.3907	0.8146	1.2387	1.8935	0.9126	1.1339	1.2741	0.9454	0.0991	0.1538	0.9059
GA27	402.0879	542.0944	0.7109	304.1199	3079335.7161	0.7092	217.2894	1050.0374	0.7680	477.7113	888.3989	0.7552	57.5518	240.5329	0.7774
GA28	35.5090	124.7410	0.6950	3.8409	152.8415	0.7037	8.3822	36.8088	0.7696	1.1454	35.0259	0.7920	0.1469	1.8115	0.7641
GA29	427.8838	539.9494	0.7111	968.1228	4322946.2564	0.6991	188.2487	851.0936	0.7713	569.6051	888.7063	0.7893	102.9252	227.6960	0.7797

GA MODELS	B6			B7			B8			B9			B10		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA30	103.2320	179.9585	0.7057	92.0564	190.2894	0.6976	36.1359	74.6165	0.7768	39.4383	125.6971	0.7707	0.8860	3.5689	0.7493
GA31	391.4403	460.6875	0.8724	301.2892	285711.9473	0.8615	129.7590	350.6888	0.9507	440.5983	677.7256	0.9775	85.6465	153.2803	0.9512
GA32	2.9417	6.4290	0.8664	0.1139	0.2853	0.8395	1.1079	1.7425	0.9444	1.0838	1.1926	0.9557	0.0662	0.1121	0.9451
GA33	315.2313	529.5639	0.7370	228.8039	5115475.0932	0.7458	137.8356	753.2847	0.8063	334.2728	840.6834	0.8214	55.0469	188.1779	0.8009
GA34	5.2634	55.5829	0.7351	2.6339	57.2380	0.7138	2.2801	20.1560	0.8011	1.3751	21.6226	0.8132	0.1828	1.0506	0.7954
GA35	409.1054	528.1771	0.7400	417.9061	4583893.6643	0.7603	216.1025	919.0624	0.7895	556.8839	889.2510	0.8146	100.0765	222.8458	0.7960
GA36	39.5450	90.7256	0.7359	37.0526	98.0932	0.7333	22.7458	35.9810	0.7924	16.2173	48.4442	0.8123	0.2789	1.1072	0.7979
GA37	90.3507	104.6183	0.8454	60.8775	126.4278	0.8214	18.9497	29.5029	0.9324	35.3832	73.1900	0.9457	1.0187	3.3316	0.9232
GA38	3.4391	6.0057	0.8422	0.1162	0.2388	0.8303	1.0758	1.7474	0.9235	1.1159	1.2099	0.9488	0.0665	0.1375	0.9146
GA39	1.5641	21.1309	0.7176	1.0615	101.7077	0.7079	0.3273	8.5831	0.7631	1.0061	5.0057	0.7890	0.6149	4.2041	0.7673
GA40	42.4942	218.8039	0.7153	41.4720	274.2070	0.7081	17.5465	55.7985	0.7872	8.7695	128.9869	0.7752	0.3147	1.5633	0.7615
GA41	58.3739	124.3984	0.6981	88.2069	255.8020	0.6986	22.9012	54.1564	0.7627	12.7780	77.3091	0.7571	0.4872	6.1175	0.7679
GA42	173.3042	264.6300	0.7168	172.3341	285.0701	0.7064	40.7225	91.8296	0.7735	104.7881	261.2053	0.8092	0.7488	4.7847	0.7720
GA43	75.1637	101.8589	0.8509	87.4075	135.2853	0.8370	20.3182	27.4314	0.9344	39.0861	63.8504	0.9717	1.5211	3.4584	0.9210
GA44	3.8721	6.4169	0.8350	0.1019	0.2173	0.8202	1.1242	1.6710	0.9181	1.0681	1.1751	0.9393	0.0565	0.1152	0.9179
GA45	0.0027	16.4574	0.7099	4.2402	90.2556	0.7015	0.2964	7.9293	0.7650	1.0000	3.5371	0.7818	0.1356	2.6458	0.7619
GA46	33.0532	206.9524	0.7236	16.5920	197.8911	0.7282	14.6027	50.6905	0.7827	5.3323	103.6021	0.7929	0.2654	1.8608	0.7770
GA47	38.0738	85.9664	0.7016	104.1641	201.7288	0.7009	12.8665	45.1618	0.7901	12.5745	45.2411	0.7841	0.6331	4.4703	0.7675
GA48	169.3619	238.1593	0.7231	108.6577	232.9752	0.7005	47.1596	85.7363	0.7733	90.3429	182.6266	0.7875	0.8446	4.0097	0.7642
GA49	50.0928	86.1902	0.8712	91.0019	161.7940	0.8783	15.3377	22.5382	0.9594	33.8471	53.7314	0.9934	1.5985	3.0762	0.9545
GA50	4.0270	6.1967	0.8768	0.0718	0.2037	0.8481	1.0355	1.5587	0.9565	1.0657	1.1666	0.9636	0.0647	0.1148	0.9382
GA51	0.0136	10.9611	0.7336	0.6417	54.7744	0.7351	0.0154	3.8372	0.8026	1.0036	2.2444	0.8089	0.0952	1.8484	0.8008
GA52	38.1929	105.9806	0.7453	5.7273	106.7317	0.7299	12.2022	32.1443	0.8113	1.0673	41.1256	0.8127	0.1535	1.3928	0.7955
GA53	4.8382	38.0482	0.7426	9.7426	88.8407	0.7410	2.0153	18.5413	0.8119	1.1534	7.8754	0.8134	0.1434	1.3360	0.8017
GA54	67.8955	148.0400	0.7513	82.3959	139.5444	0.7359	19.4439	50.5363	0.8012	30.9733	84.0523	0.8051	0.1810	1.5151	0.7892
GA55	13.2738	17.9679	0.8698	0.8347	1.6975	0.8593	2.9466	4.3943	0.9715	1.5302	2.7461	0.9762	0.1774	0.4210	0.9492
GA56	1.9865	6.1137	0.8842	0.0804	0.1634	0.8575	1.2461	1.5887	0.9514	1.0413	1.1306	0.9798	0.0527	0.1180	0.9602
GA57	0.0053	19.2159	0.7481	0.3634	107.7443	0.7380	0.0751	4.3052	0.8147	1.0002	4.2020	0.8101	0.3017	3.9861	0.7977
GA58	142.9923	274.3192	0.7294	66.2256	279.9860	0.7566	20.0354	77.8778	0.8180	33.3005	168.8285	0.8187	0.2314	1.4732	0.8098
GA59	18.7469	101.6759	0.7336	95.8006	223.9068	0.7454	16.4276	41.2292	0.8161	25.7033	74.3065	0.8203	1.3579	7.6290	0.8035

GA MODELS	B6			B7			B8			B9			B10		
	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)	Min	Average	Time(Avg)
GA60	186.1092	289.2131	0.7631	174.9533	340.3696	0.7465	73.1621	98.9256	0.8167	155.6725	288.5292	0.8329	1.8099	4.7124	0.8149
GA61	13.1477	18.7011	0.8845	0.7104	1.5429	0.8820	2.8638	4.4065	0.9651	1.6128	2.3474	0.9808	0.3044	0.4626	0.9517
GA62	2.2620	5.2315	0.8779	0.0957	0.1520	0.8525	0.9417	1.4554	0.9696	1.0776	1.1364	0.9800	0.0454	0.1152	0.9531
GA63	0.0487	28.4248	0.7408	0.6862	83.8920	0.7496	0.2464	8.5266	0.8145	1.0002	4.3106	0.8118	0.6748	3.7156	0.8079
GA64	58.6793	249.3924	0.7499	132.4535	252.3221	0.7304	22.5156	67.7905	0.8166	6.5885	170.6875	0.8260	0.2768	1.7615	0.8031
GA65	19.4011	80.5243	0.7524	63.3042	191.6334	0.7554	9.9514	37.3059	0.8119	3.4423	30.3181	0.8504	0.8415	4.9305	0.8000
GA66	161.9997	258.7963	0.7525	152.2355	285.2151	0.7364	57.5080	99.8851	0.8093	115.9379	234.9207	0.8170	1.3226	5.0007	0.8067
GA67	10.9426	16.6235	0.9076	0.7572	1.7335	0.9014	2.4479	3.6719	0.9893	1.3774	2.2074	1.0136	0.1398	0.3798	0.9909
GA68	1.6291	4.5276	0.9110	0.0651	0.1261	0.8868	0.9938	1.3836	0.9783	1.0650	1.1260	1.0039	0.0338	0.1229	0.9857
GA69	0.0074	15.0851	0.7716	1.6937	59.3910	0.7720	0.3448	9.2888	0.8360	1.0175	2.2717	0.8499	0.0742	1.8350	0.8239
GA70	66.2012	148.4557	0.7822	48.6952	155.4830	0.7881	14.4436	41.3564	0.8295	1.1028	77.3162	0.8483	0.2990	1.9263	0.8307
GA71	2.2427	31.8791	0.7825	1.0616	100.7190	0.7823	2.7388	15.8307	0.8204	1.1495	5.6752	0.8509	0.1407	1.3905	0.8382
GA72	87.4279	180.1602	0.7884	103.2502	204.7304	0.7802	31.4729	63.4605	0.8193	30.3588	118.7648	0.8558	0.2073	2.8370	0.8411

Poster

Performance of Different Operation Techniques Applied in Genetic Algorithm Towards Benchmark Functions

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Project Supervisor : Dr. Lim Seng Poh

Project Overview

Genetic Algorithm is an important topic in this highly competitive world. This is because GA is able to solve the optimisation problem. The importance of optimisation has been revealed by people in past. Nowadays, optimisation helps to reduce cost and increase profit. However, the performance of GA is always not considered by the researcher due to the lack of knowledge and time consuming. Therefore, this project will present the importance on the combinations of different operation techniques in GA.

Problem Statement

i.Researchers are not able to obtain optimum result due to lack of knowledge in GA.

ii.Performance of GA will be affected when different operation techniques are implemented in GA.

Project Objectives

i. To analyse different operation techniques in GA.

ii. To identify the best combination of operation techniques in GA using benchmark functions along with different parameter settings.

Project Scope

i. 4 Selection Operations: Roulette Wheel, Random, Rank, Tournament

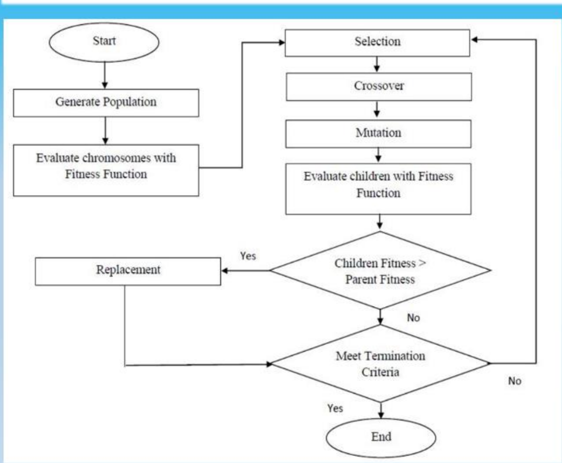
ii. 3 Crossover Operations: Single Point, Two Point, Uniform

iii. 3 Mutation Operations: Flipping, Interchanging, Reversing

iv. 2 Replacement Operations: Random, Weak Parent

v. 10 benchmark functions are used as fitness function

vi.C++ programming language is used



Flow of GA

Result

Experiments with different parameter settings are conducted. The performance of each GA model toward benchmark functions is obtained. The best GA model consists of Tournament Selection, Uniform Crossover, Flipping Mutation and Weak Parent Replacement.

Conclusion

By comparing the performance of different GA models, the best GA model will be determined. In addition, this provides support to the researcher in doing optimisation problem. This helps the researchers to improve the efficiency of their research.

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FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY

Full Name(s) of Candidate(s)	Ong Chin Hwa
ID Number(s)	15ACB01696
Programme / Course	Bachelor of Computer Science
Title of Final Year Project	Performance of Different Operation Techniques Applied in Genetic Algorithm towards Benchmark Functions

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