INCORPORATING SPACE DIVISION AT INITIALIZATION PHASE OF BEES ALGORITHM

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by

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ABSTRAK

Bees Algorithm adalah algorithma pengoptimuman berasaskan populasi yang mengilhamkan tingkah laku semulajadi lebah mencari makanan. Pada fasa permulaan *Bees Algorithm*, pengedaran rawak seragam digunakan di mana rawak membantu sistem untuk memberi penyelesaian baru terutamanya dalam problem pengoptimuman yang kompleks seperti bidang komputer sains, kawalan kejuruteraan dan kejuruteraan mekanikal. Namun begitu, hal ini menyebabkan kelajuan konvergen lambat dalam memproseskan data. Oleh yang demikian, untuk meningkatkan kelajuan konvergen, teknik *Search Space Division* digabungkan dengan *Bees Algorithm*. Search Space Division mempunyai keupayaan untuk beroperasi dalam dimensi yang tinggi. Keberkesanan teknik baru dinilai dengan membandingkan kadar berjaya dengan *Bees Algorithm* dan *quick Artificial Bee Colony*. Kadar berjaya teknik baru mengatasi algorithma yang lain. Keberkesanan teknik baru dibandingkan dengan *Bees Algorithm* di mana beberapa parameter berbeza diuji dengan didedahkan terhadap pelbagai jenis ujian penanda-aras. Keputusan menunjukkan kesemua empat parameter berjaya memperoleh keputusan yang baik. Menurut perbandingan *mean evaluation* kedua-dua algorithma menunjukkan teknik baru mempunyai kelajuan konvergen yang lebih baik daripada *Bees Algorithm*. Walaubagaimanapun, ujian statistic t-test, kelajuan konvergen teknik baru sama dengan *Bees Algorithm*. Oleh yang demikian, penggabungan *Search Space Division* dalam fasa permulaan *Bees Algorithm* merupakan penyelidikan untuk mendedahkan kelajuan convergen algorithma baru.

ABSTRACT

Bees Algorithm is a population-based optimization algorithm that mimics the natural foraging behavior of swarm bees. At initialization phase in Bees Algorithm, uniform random distribution is used where the randomness help the system to sample new solutions particularly in complex optimization problems such as in computer science, engineering control and mechanical design. Unfortunately this leads to slow convergence rate to the optimum solution in Bees Algorithm. Therefore, in order to increase the convergence speed, Search Space Division (SSD) is implemented at initialization phase of the existing Bees Algorithm. Search Space Division is a novel initialization method that can easily work on high dimension. The trustworthiness of new improved algorithm is evaluated by comparing success rate with Bees Algorithm and quick Artificial Bee Colony. Success rate of Search Space Division Bees Algorithm outperformed both Bees Algorithm and quick Artificial Bee Colony. The efficiency of the new improved method in terms of convergence speed is compared with standard Bees Algorithm. Both algorithms were tested by using different parameter settings on selected benchmark test functions. Results show that all four parameters have equally good results on improved algorithm. According to comparison of mean evaluation of both algorithms shows significant improvement of new algorithm in convergence speed than existing Bees Algorithm. However, t-test shows newly improved convergence speed is on par with standard Bees Algorithm. Thus, incorporating Search Space Division in initialization phase of Bees Algorithm serves as a preliminary work to reveal the convergence speed of the newly improved algorithm.

DEDICATION

This thesis is dedicated to
my respectful father, Chelliah
my beloved mother, Sivakami
my lovely sisters, Thenmoly and Ponnarasi
for their unconditional love, support, care and encouragement.
I couldn't have done this without you people.
Thank you so much for always being there for me.
You are the best thing that ever happened to me!

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LIST OF ABBREVIATIONS

ABC - Artificial Bee Colony

ACO - Ant Colony Optimization

BA - Bees Algorithm

EA - Evolutionary Algorithm

GA - Genetic Algorithm

PSO - Particle Swarm Intelligence

SI - Swarm Intelligence

SSD - Search Space Division

SSDBA - Search Space Division Bees Algorithm

CHAPTER 1
INTRODUCTION

This chapter discusses the project background, problem statement, objective and scope of the project. The title of this project is Incorporating Space Division at Initialization Phase of Bees Algorithm. This project will focus on Bees Algorithm.

1.1 Project Background

Optimization is a process of finding the best possible or desirable solution to solve a problem (Binitha and Sathya, 2012). In this advanced era, many real world engineering programs need the manipulation of a number of system variables in order to optimize a given quality parameter such as the value or performance of a product and the reliability and accuracy of a process (Pham and Castellani, 2009). Optimization algorithm can be categorized either as deterministic or stochastic in nature (Binitha and Sathya, 2012). Artificial Intelligence (AI) is a program developed to make machines do things that would require intelligence if done by human. It is applied in order to help engineers to solve problems related to engineering (Negnevitsky, 2002).

Nowadays, nature-inspired metaheuristic have become very popular among researchers in solving complex problems. Swarm Intelligence (SI) is an AI discipline concern with the design of intelligent multi-agent system. SI inspired by collective behavior of animal societies and social insects (Blum and Li, 2008). Examples of SI are Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Artificial Bee Colony (ABC) and Bees Algorithm (BA).

BA is a population-based optimization algorithm, developed in 2005 that mimics the natural foraging behavior of a swarm of bees (Pham *et al*., 2009). The algorithm performs two types of search namely random explorative search and exploitative neighborhood search. BA is proven to be highly competitive in terms of learning speed and accuracy compared to the other swarm algorithms.

1.2 Problem Statement

At initialization phase in BA, uniform random distribution is used where the randomness help the system to sample new solutions particularly in complex problems. Unfortunately, this leads to slow convergence rate to the optimum solution in BA just like other stochastic algorithms (Alfi and Khosravi, 2012; Hussein *et al.,* 2013).

To overcome this problem, instead of using a uniform random distribution for the local bees' initialization, this project proposes the use of the Search Space Division (SSD). According to He *et al.* (2014), SSD is a novel initialization method which provides high quality of initial solution. It has been used by other researchers in swarm-based optimizer such as He *et al.* (2014) in ABC algorithm and Tsutsui *et al.* (1997) in Genetic Algorithm (GA). Hence the outcomes of the proposed algorithm can be analyzed and compared with other swarm based algorithms such as ABC.

1.3 Objective

The objectives of this research are:

i. To demonstrate the use of Search Space Division in Bees Algorithm to improve its convergence speed.
ii. To compare the proposed algorithm with the standard Bees Algorithm and other swarm-based algorithms.
iii. To propose suitable parameter that suits the proposed algorithm.

1.4 Scope of the project

This research focuses on the performance of the Bees Algorithm by using Search Space Division technique. The proposed algorithm shall be implemented by using computer with MATLAB software is installed in it. Besides that, this research also studies the works done by other researchers including development of Search Space Division in other swarm-based algorithms. Then the proposed algorithm shall be applied to selected benchmark test functions in order to determine it convergence speed for each function. Finally, the outcomes of the proposed algorithm is analyzed and compared with other swarm-based algorithms.

1.5 Report Structure

The remainder of the report of research is organized as follows:

Chapter 1 is the introduction of the research. Briefly, this chapter consists of project background, problem statement, objectives and scope of the project.

Chapter 2 is the literature review. This chapter discusses the theories that relevant and related to the title of this research. Apart from that, research on swarm-based algorithm done by others is also discussed.

Chapter 3 is the methodology of the report. This chapter presents and briefly discusses the review of the methodology for entire project that need to be carried out in order to achieve the objective of this project.

Chapter 4 is about project result and discussion. This chapter analyzes and compares the results obtained. Moreover discussion of the result is done by referring to other researcher papers.

Chapter 5 is about conclusion and recommendation. The whole content of this project is reviewed and summarized. The recommendation for future work is discussed as well.

CHAPTER 2
LITERATURE REVIEW

This chapter is about review of the previous related studies and research paper in the fields of swarm based optimization techniques findings and methodology. This chapter in detail discusses about the theories of Evolutionary Algorithm (EA), Genetic Algorithm (GA), Swarm Intelligence (SI), Ant Colony Optimization (ACO), Particle Swarm Intelligence (PSO), Artificial Bee Colony (ABC), Bees Algorithm (BA) and finally, Search Space Division (SSD).

2.1 Optimization

Basically optimization is used all over, from design of engineering to planning of business as well as from the routing of the internet to holiday planning. Among these activities, certain objectives or optimization of profit, quality and time tried to be achieved. As in real world application, time, money and resources are always limited. Thus, optimal solution is needed to utilize these valuable resources under different constraints (Yang, 2011).

According to Chinneck (2010), practical optimization is described as art and science of allocating scarce resources to the best potential effect. Most of the large scale optimization techniques and methods developed during World War II. Back then, had to face the biggest logistical issues caused by a large number of armies with millions of engines and machines. Simplex method is a first practical, and large scale optimization technique. Its fundamentals were developed during the war.

In an optimization process, usually will start with a real life problem with full of details and complexities. However, some are relevant while some are not. Based on this, essential elements are extracted. Then, an algorithm or solution technique is applied to it. Meanwhile, for practical problems, the computer will carry out the necessary calculations (Sinebe *et al.*, 2014). Figure 2.1 shows the flow of optimization process.

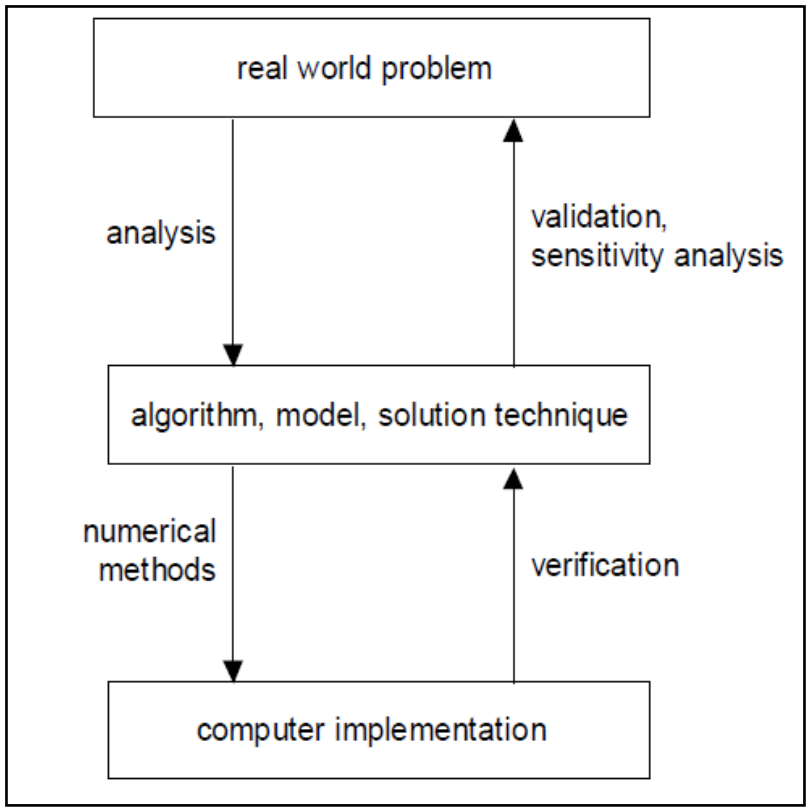

Figure 2.1: Optimization Process (Sinebe et al., 2014).

There is a loss of realism that cannot be avoided as one move down from real world problem to algorithm, model, or solution technique, and lastly to computer implementation. The process after computer implementation is verification. Verification is a process of conformation of simulation model is converted into a computer program without any mistake or error. Meanwhile, in validation, a model undergoes testing and improvement processes in order to enhance its validity. Validation is necessary to ensure the model truly represents what

is obtainable in real system. Sensitivity analysis determines how sensitive the model parameters can be varied, respectively (Chinneck, 2010).

Optimization algorithms are well known as search methods. The goal of the algorithm is to obtain an optimal solution to a problem. This is in order to fulfill one or more objective functions, perhaps subject to a set of constraint (Yuce *et al*., 2013). Bio inspired approaches can solve an impressive array of problems and solve complex problems in entire keys of computer science. The two most successful and predominant algorithms of Bio Inspired Algorithm are Evolutionary Algorithms and Swarm based Algorithms. The algorithms take inspiration of natural evolution and collective behavior in animals (Binitha and Sathya, 2012). The algorithms discussed briefly in following sections.

2.2 Evolutionary Algorithm

Evolutionary algorithms (EA) are population based metaheuristic optimization algorithms that apply biology-inspired mechanisms in order to improve asset of solution candidates iteratively. Examples of biology-inspired mechanisms are mutation, crossover, natural selection, and survival of the fittest (Weise, 2009). At every generation, process of selection individuals develops a new set of estimations. The selection is carried out based on their performance of fitness in the problem domain. Then, process of breeding them together is carried out by utilizing operators borrowed from natural genetics. This process leads to the evolution populations of individuals that are fit better in their environment. This described as better compared to the individuals that were produced as in natural adaptation (Pohlheim, 2006).

According to Weise (2009), there are single-objective and multi-objective evolutionary algorithm. Multi-objective evolutionary algorithm is used for optimizing multiple and possible conflicting criteria. Figure below shows structure of a single population Evolutionary Algorithm.

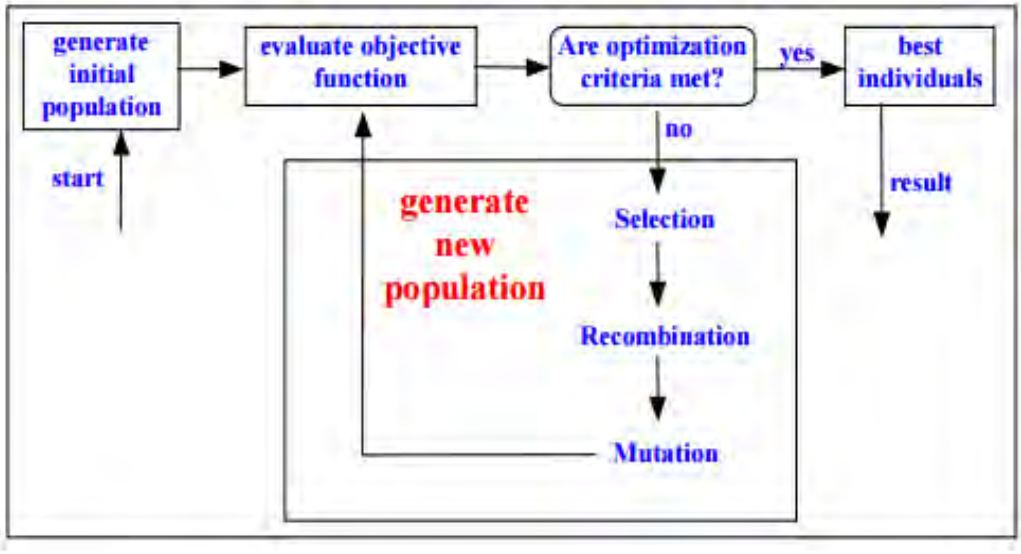

Figure 2.2: Structure of a single population EA (Pohlheim, 2006).

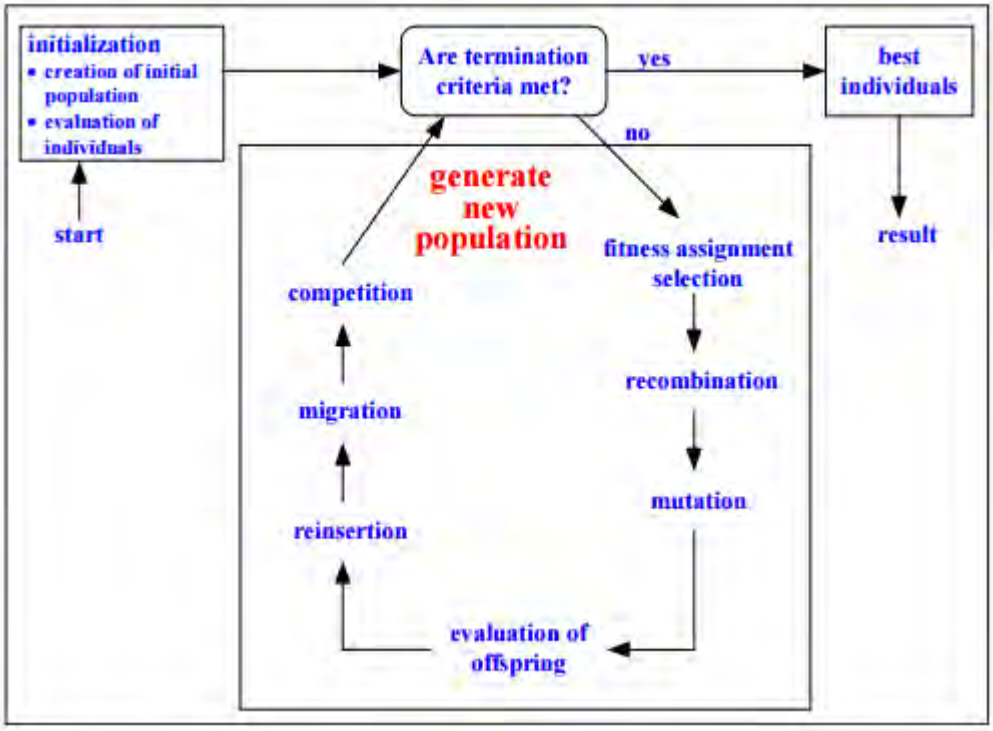

Figure 2.3: Structure of extended multi population EA (Pohlheim, 2006).

Figure 2.3 shows structure of extended multi population Evolutionary Algorithm. There have been three main independent implementation instances of EA. Firstly, Genetic

Algorithm created by Holland in 1970s and thoroughly reviewed by Goldgberg. Secondly, Rechenburg and Schwefel created Evolution Strategies (1960s) in Germany. Lastly, L.J.Fogel is the first person to develop Evolutionary Programming in 1960s and subsequently improved by D.B.Fogel (Weise, 2009). Genetic Algorithm will be discussed in more detail in next section.

2.2.1 Genetic Algorithm

According to Li *et al.* (2016), genetic algorithm (GA) is based on natural evolution of Darwin's theory, "survival of the fittest" and Mendels genetic variation theory. It was introduced by John Holland in 1970s which is a search and optimization algorithm. Basically, GA is a process of imitation of the way biological evolution works.

Better solutions evolve from generation to generation until solution close to optimal is obtained. GA uses three main operations to produce new generation from old ones. The operations are selection, crossover and mutation (Abuiziah and Shakarneh, 2013). However, there are still chances to utilize other operations such as colonization-extinction, regrouping, or migration in genetic algorithm (Akbari and Ziarati, 2011). Figure 2.4 shows the basic pseudocode of Genetic Algorithm.

```
Procedure Genetic Algorithm {
        t=1;
Initialize population (t);
        While(max number of generates)
{
Evaluate fitness population (t);
Parent (t)=Select Parents (Population (t));
Offspring (t)=Reproduction operator (parents (t));
Population =Generational replacement (offspring)
T=t+1; }
```

Figure 2.4: Basic pseudocode of GA (Maheshwari *et al.*, 2016).

According to Jebari and Madiafi (2013), evolution begins from a randomly generated individuals population that been selected from search space which is an iterative process. The population is known as generation in every iteration. Objective function value in each optimization problem solved is fitness. Fitness of each individual in each generation is evaluated. The more fit individuals selected stochastically from existing population. Usually the algorithm will terminate when either satisfactory level has been achieved or maximum number of generations has been produced.

Although solutions are preferably represented in binary as strings of 0s and 1s, the other encodings are probable too. Every candidate solution represented as an array of bits. In GA, string will be tested to get score which indicate how good the solution is. The new generation is utilized for the following iteration of algorithm. Usually biologically reproduction based on the use of two parents. However, it is stated that more than two parents capable of generating higher quality chromosomes (Ting, 2005).

As indicated by Abuiziah and Shakarneh (2013), in each cell of living things contains chromosome that carry genetic information in the form of genes. Reproduction of new chromosomes involves recombination of two chromosomes by swapping one segment of one chromosome with corresponding segment on another chromosome. It is carried out randomly. The six type of crossover are single point crossover, two points crossover, intermediate (uniform) crossover, arithmetic crossover, heuristic crossover and ring crossover. Figure below shows the different type of crossover. Figure 2.5 shows different type of crossover. Meanwhile, figure 2.6 shows the process of mutation.

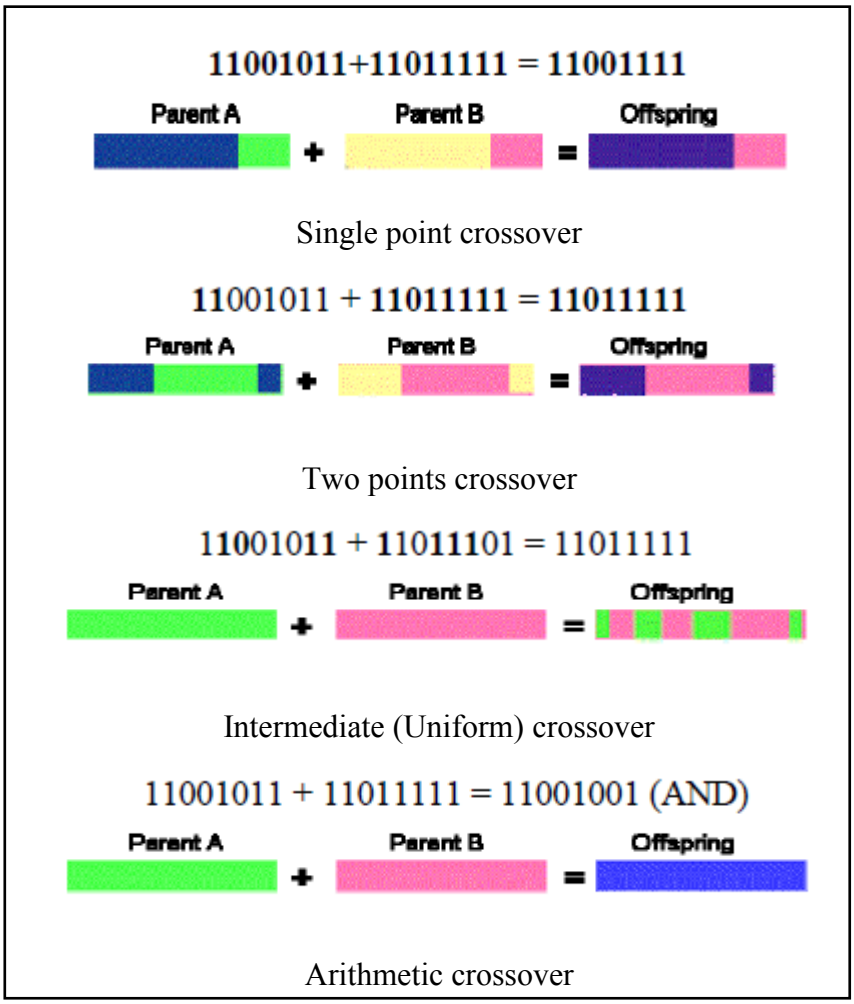

Figure 2.5: Different type of crossover (Abuiziah and Shakarneh, 2013).

Mutation occurred when randomly selected bits have been flopped. Usually mutation probability is small.

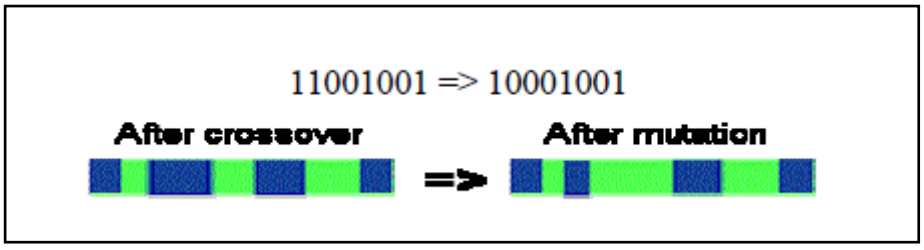

Figure 2.6: Mutation process (Abuiziah and Shakarneh, 2013).

According to Abuiziah and Shakarneh (2013), simple GA follows these steps and is summarized in figure 2.7.

Step 1: Determine the initial population of creatures.

Step 2: Determine the fitness of the population.

Step 3: Reproduce the population using the fittest parents of the last generation.

Step 4: Determine the crossover point which can also be random.

Step 5: Determine if mutation occurs and if so on which creature(s).

Step 6: Repeat from step 2 with the new population until satisfied population is produced.

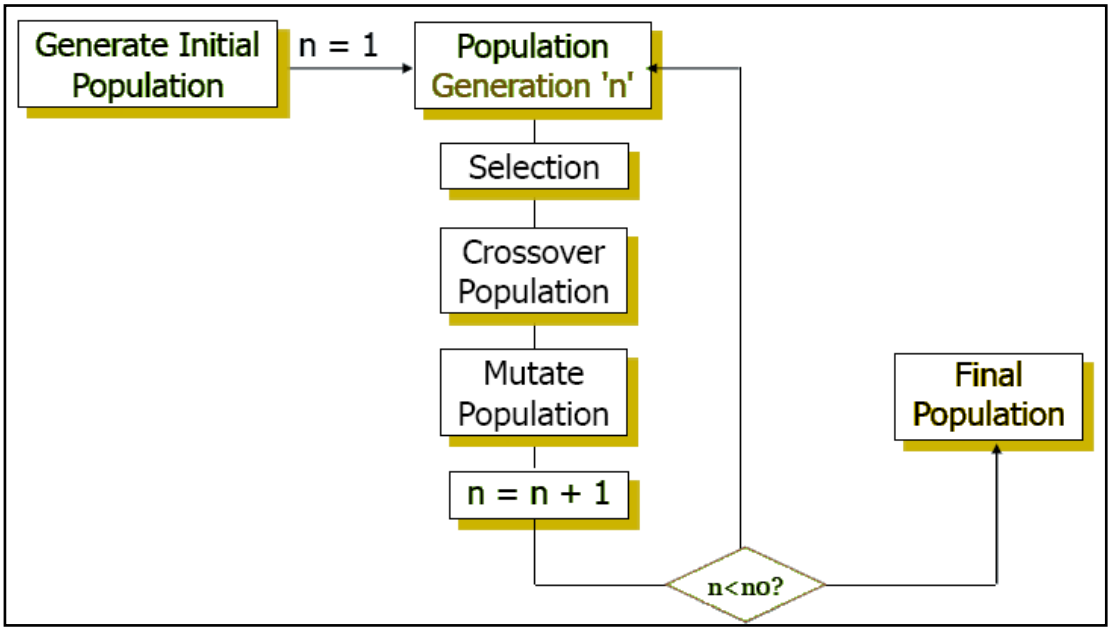

Figure 2.7: GA flowchart (Abuiziah and Shakarneh, 2013).

According to Kar (2016), GA widely used in engineering, physics, mathematics, computer science, and astronomy and material science areas. GA used for finding among alternatives for maximization or minimization problems such as sorting problems, travelling salesman problem, multi-objective decision making, multi-criteria decision making and constrained optimization problem. Applications of GA are network analysis, job scheduling, intrusion detection, dispatch problems, navigation and load balancing problems.