GENETIC ALGORITHM TO SOLVE PCB COMPONENT PLACEMENT MODELLED AS TRAVELLING SALESMAN PROBLEM

MOHD KHAZZARUL KHAZREEN BIN MOHD ZAIDI

UNIVERSITI MALAYSIA PAHANG

ABSTRACT

This thesis discuss about Genetic Algorithm to solve PCB component placement modeled as Travelling Salesman Problem (TSP). Genetic algorithms are a class of stochastic search algorithms based on biological evolution. GA represents an iterative process. Each iteration called generation. A typical number of generations for a simple GA can range from 50 to over 500. The entire set of generations is called run. At the end of the run, the result expected is to find one or more highly fit chromosomes. The travelling salesman problem (TSP) is one of the most widely discussed problems in combinatorial optimization. There are cities and distance given between the cities. Travelling salesman has to visit all of them, but he does not to travel very much. Then task is to find a sequence or route of cities to minimize travelling distance and time. The problem statement is to find the most optimum result for TSP problem which means finding the optimum time and distances for the travelling salesman to visit all the cities and return back to his home city. To achieve this result, genetic algorithm technique was used. There are several objectives set for this research which all of them connected to the title itself which is about genetic algorithm as an alternative to solve PCB component modeled as TSP problem. At the end of the project, we will be able to see how genetic algorithm used to get optimize result for TSP.

ABSTRAK

Tesis ini membincangkan tentang Algoritma Genetik untuk menyelesaikan penempatan komponen PCB dimodelkan sebagai Masalah Perjalanan Jurujual (TSP). Algoritma genetik adalah kelas algoritma carian stokastik berdasarkan evolusi biologi. GA merupakan proses lelaran. Setiap lelaran dipanggil generasi. Beberapa biasa generasi untuk GA mudah boleh terdiri daripada 50 kepada lebih 500. Set keseluruhan generasi dipanggil dijalankan. Pada akhir jangka masa, hasil yang diharapkan adalah untuk mencari satu atau lebih kromosom sangat patut. Masalah jurujual kembara (TSP) adalah salah satu masalah yang paling banyak dibincangkan dalam pengoptimuman kombinatorik. Terdapat bandar-bandar dan jarak diberikan antara bandar-bandar. Perjalanan jurujual telah melawat mereka semua, tetapi dia tidak pergi sangat. Kemudian tugas adalah untuk mencari urutan atau laluan di bandar-bandar untuk mengurangkan jarak perjalanan dan masa. Pernyataan masalah adalah untuk mencari hasil yang paling optimum bagi masalah TSP yang bermaksud mencari masa yang optimum dan jarak jurujual perjalanan untuk melawat semua bandar-bandar dan kembali ke bandar rumahnya. Untuk mencapai keputusan ini, teknik algoritma genetik telah digunakan. Terdapat beberapa objektif yang ditetapkan bagi kajian ini yang mana semua mereka yang berkaitan dengan tajuk itu sendiri iaitu kira-kira algoritma genetik sebagai alternatif untuk menyelesaikan komponen PCB dimodelkan sebagai masalah TSP. Pada akhir projek ini, kita akan dapat melihat bagaimana algoritma genetik yang digunakan untuk mendapatkan hasil mengoptimumkan untuk TSP.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

TSP	Travelling Salesman Problem
GA	Genetic Algorithm
PCB	Printed Circuit Board
PMX	Partially Mapped Crossover
OX	Order Crossover
LOX	Linear Order Crossover
CX	Cycle Crossover

LIST OF EQUATION

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

The travelling salesman problem (TSP) is a well-known and important combinatorial optimization problem. The simpler word to describe this is to find the shortest route which visits each city and returns to initial city. TSP is one of the most difficult and challenging problem because it is an NP-complete problem. NP-complete problem means a problem that must be solved but there is no fast solution to solve it. This problem also has no efficient way to locate a solution and also the time taken to solve the problem will continue increase proportional to the size of the problem which means the bigger the problem the longer the time taken to solve the problem. The only solution to find the most optimal results is by examining all the possible solution. Some typical example of TSP is scheduling of service calls at cable firms, the delivery of meals to homebound persons, the scheduling of stacker cranes in warehouses, the routing of trucks for parcel pickup and many others.

Genetic algorithm (GA) is an optimization technique which similar to natural evolution. In natural gas usually involve reproduction, selection, mutation and crossover. This method usually used to solve optimization problem and search problem. The input of GAs is a group of individuals which called initial population. In this method, it must evaluate and analyze all of the individuals and select the best individuals or in GAs word the fittest individual in the population. Then the initial population will be developed by crossover and mutation technique.

MATLAB is a tool which is used to develop a program for GAs which will be used to solve TSP. MATLAB is a special-purpose computer program optimized to perform engineering and scientific calculations. It is high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solution are expressed in familiar mathematical notation.

1.2 PROBLEM STATEMENT

The problem is to the less productivity of PCB board due to slower component placement process. In order to increase the productivity, faster component placement on PCB board should be done. The slower component placement process may be due to the design of the PCB itself which can slow the placement process. Another problem that involves is the component placement priority. In order to get optimum time of manufacture, component selection which needs to be placed first should be properly set. Another problem that appears in PCB component placement process is the component placement sequence itself.

1.3 RESEARCH OBJECTIVES

There are several main objectives of the project which is:

- To understand the concept of genetic algorithm and travelling salesman problem that can be modeled to optimize PCB component placement
- To be able to apply the genetic algorithm to solve optimization problems particularly in solving the travelling salesman

1.4 RESEARCH SCOPE

Genetic algorithms (GAs) are intelligent search strategies which have been successfully used to find a solution for many complex problems. Implementation of GA in solving problems can help to find near optimal solutions for the problems. In this research, GA principle was used for solving TSP. This TSP consists of n cities which need to be visited by the travelling salesman. The goal is to visit all the cities and return back to its original city within optimum time and distance. The scope of the project is to apply TSP concept using GA to one of the case study in the industry. Another scope is to use Matlab as a problem solving tool.

1.5 SUMMARY

This chapter presents the introduction of the project. It gives a basic understanding of the project which will be done. The problems statements of the project are identified. After the problem is known, research objective exists. The objective of the project was done based on the problem statements itself. Important information can be found is the scope of the research. The scope of the project is acting as the constraint of the project parameter. It will limit the search space, the population and etc.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter explains the research and methods that were used by others in order to solve optimization problems such as TSP. There was also some explanation about genetic algorithm (GA) method and the steps that we need to follow to solve the problem using the GA method. Inside if this chapter also will explain and elaborate more on how the GA method can be used to get the optimum or near the optimum result for TSP.

2.2 GENETIC ALGORITHM OPERATION

The GA operation is based on the Darwinian principle of survival of the fittest and it implies that the 'fitter' individuals are more likely to survive and have a greater chance of passing their 'good' genetic feature to the next generation. The fitness of each individual is determined using fitness function. The fitness function establishes the basis for selecting chromosomes that will be mated during reproduction. Each individual fitness will be calculated and a pair of chromosomes will be selected for mating. Parent chromosomes are selected with a probability related to their fitness. Highly fit chromosomes have a higher probability of being selected for mating than less fit chromosomes. The offspring will be created after performing genetic operator which is crossover and mutation. Once crossover and mutation is done, a new generation is formed and the process is repeated until some stopping criteria have been reached.

2.3 SELECTION METHOD

Selection is a genetic operator that chooses a chromosome from the current generation population for inclusion in the next generation population. Before making it into the next generation population, selected chromosomes may undergo crossover and mutation in which case the offspring are actually the ones that make it into the next generation population.

2.3.1 TOURNAMENT SELECTION

According to Brad L. Miller and David E. Goldberg (1995) GAs uses selection mechanism to select individuals from the population to insert into a mating pool. Each individual from the mating pool is used to generate new offspring which will be the beginning of the new generation. Better individuals will be more likely to be chosen for the mating pool. The selection pressure is the degree to which the better individuals are favored. In other words, the higher the selection pressure the more the better individuals are favored. The quality of the population fitness will be improved due to the selection pressure in Gas. The rate of convergence of GAs largely determined by selection pressure. The higher the selection pressure will also increase the convergence rate of individuals in GAs. The advantages of GAs are it can determine optimal and near-optimal solution in a wide range of selection pressure. However there are also some disadvantages of using tournament selection in this problem. If the selection pressure is too low, the convergence rate will be slow and will cause GAs to take longer time to get the optimal solution. Another one is that the GAs may be prematurely converging to an incorrect solution due to high pressure.

Tournament selection provides selection pressure by holding tournament among n competitor which n is the tournament size. The winner of the tournament selection is the individuals which comprise the highest fitness among all competitors. The winner will be inserted to the mating pool which will improve the fitness of the new offspring which is higher than the average population fitness. Selection pressure could be increased by enlarging the tournament size n as the winner from the larger tournament size will have a better fitness compared to smaller tournament size.

2.3.3 ROULETTE WHEEL SELECTION

In keeping the ideas of natural selection, we assume that stronger individual, that is, those with higher fitness values are more likely to mate than the weaker ones. Parents which have the probability directly proportional to its fitness values are selected to mate rather than the weaker fitness values parents. This type of technique is called roulette wheel selection method. The idea behind the roulette wheel selection is that each individual is given a chance to become a parent in proportion to its fitness. The selection method of parents is by spinning the roulette wheels with the size of the slot on the roulette wheel represent each parent proportional to their fitness. Obviously, parents which have higher values of fitness will have more chances to be chosen due to their large slot size of the roulette wheel.

$$Pi = \frac{Fi}{\sum_{i=1}^{n} Fi} \tag{2.1}$$

If the wheel spins, one of the slots will finally stop at selection point and most probably the largest area of the slot. However, the entire slot has their chances but the probability that the larger area of slot to be selected is obviously higher than the smaller area of the slot. By repeatedly spinning the wheel and each time the wheel stop spinning an individual will be selected, the better individual will be chosen more often than the poorer ones, thus fulfilling the requirements of survival of the fittest. The advantage of roulette wheel selection is that it does not eliminate any individuals which mean all the individuals had chances to be selected; hence, the diversity in the population is preserved.

$$\bar{F} = \sum_{i=1}^{n} Fi \tag{2.2}$$

This type of selection often used in solving TSP. TSP aims at finding out the individual with higher fitness. The higher the fitness value of an individual the shorter the route length and the higher selected probability will be. The lower fitness value of individuals will have the longest route length which will lower selected probability.

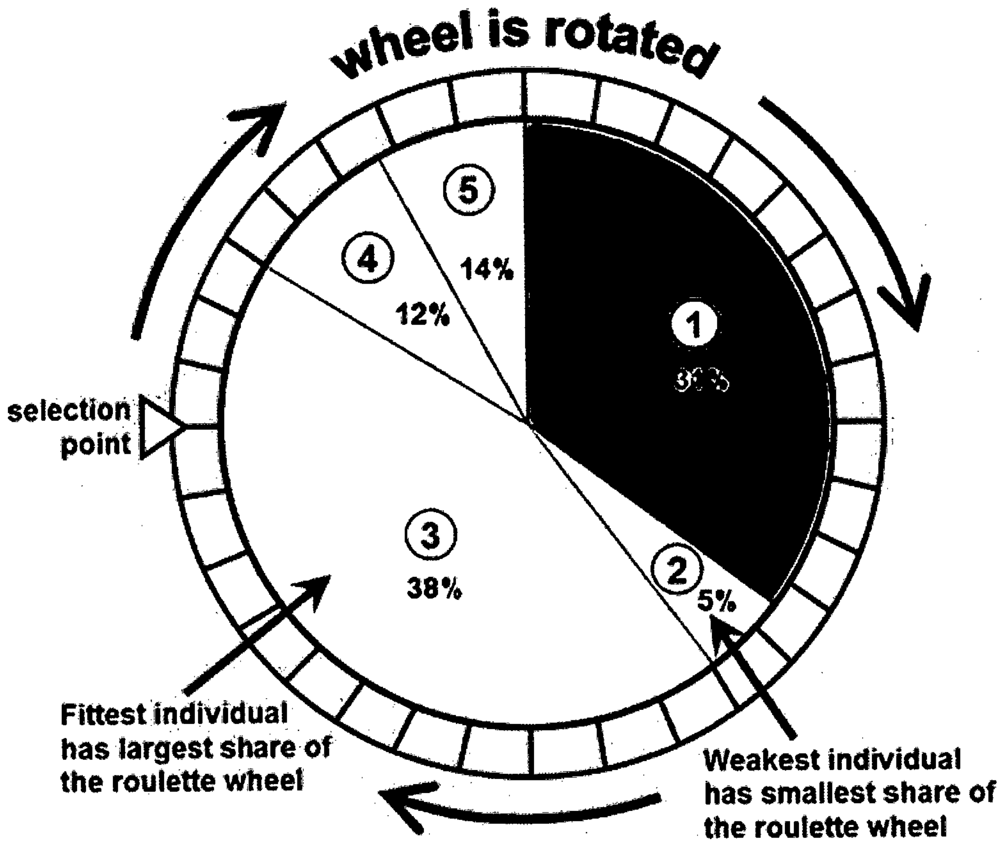


Figure 2.1 Roulette wheel selections

2.4 CROSSOVER

Crossover happens between two chromosomes to produce a new offspring that has genes from both parents. There are three types of crossover that can happen. The first one is one point crossover. For this type of crossover only one part of the first parent is copied and the rest is taken in the same order as in the second part. Another type is a two point crossover which for this type of crossover two parts of the first parent are copied and the rest between is taken in the same order as in the second parent. The crossing over will produce offspring. The third type of crossover is cloning crossover. This happens when crossover does not take place between the chromosomes and will produce exact same copies as their parents. After selection and crossover the average fitness of the chromosome population should be improved.

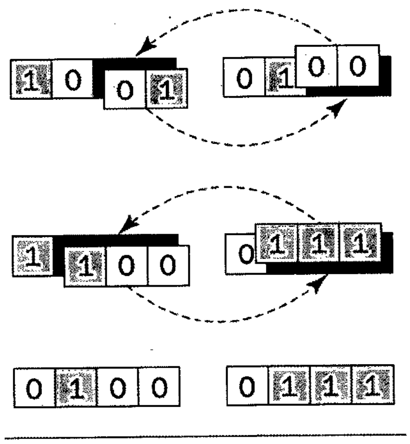


Figure 2.2 Basic crossover

2.4.1 CROSSOVER MECHANISM

[10] Some of the most popular generic permutation-based crossover techniques in algorithm are **Partially Mapped Crossover (PMX)**, **Order Crossover (OX), Linear Order Crossover (LOX)** and **Cycle Crossover (CX)**. In **PMX** method, two crossover points are selected at random and PMX proceeds by position wise exchanges. The two crossover points give a matching selection. It affects cross by position-by-position exchange operations. In this method parents are mapped to each other, hence we can also call it partially mapped crossover. The PMX crossover exploits important similarities in the value and ordering simultaneously when used with reproductive plan. Order crossover (OX) was proposed by Darwis (1985). This type of crossover keeping traits to their parents' chromosomes, it also takes relative order of allele values into account while performing the crossover option. The OX exploits a property of the path representation, that the order of cities is important. It constructs an offspring by choosing a sub tour of one parent and preserving the relative order of the cities of the other parent. LOX is the modified version of order crossover which is proposed by Falkenauer and Bouffix. The crossover between chromosomes occurs normally

like OX but when sliding the parent values around to fit in the remaining open slots of the child's chromosomes, they are allowed to slide to the left or right. This will ensure that the offspring to maintain its relative ordering while preserving the beginning and ending values. Cycle crossover was proposed by Oliver et al (1987). This type of crossover is trying to produce offspring in such way that each city and its position come from one of the parents. It is also a little bit different to PMX and OX. The chromosomes are not spitted to form segments to swap. We can choose the first elements and the rest of the elements will randomly select.

PARTIALLY MAPPED CROSSOVER (PMX): proposed by Goldberg and Lingle (1985)

Basic procedure of PMX

Step 1: select two positions along the string uniformly at random. The substrings defined by the two positions are called mapping section

Step 2: exchange two substrings between parents to produce proto-children

Step 3: determine the mapping relationship between two mapping sections

Step 4: legalize offspring with the mapping relationship

1. Select the substring at random

Parent 1	1	2	3	4	5	6	7	8	9
Parent 2	5	4	6	9	2	1	7	8	3

2. Exchange substring between parents

Proto-child 1	1	2	6	9	2	1	7	8	9
Proto-child 2	5	4	3	4	5	6	7	8	3

3. Determine mapping relationship

6	9	2	1
3	4	5	6

4. Legalize offspring mapping relationship

3	5	6	9	2	1	7	8	4
2	9	3	4	5	6	7	8	1

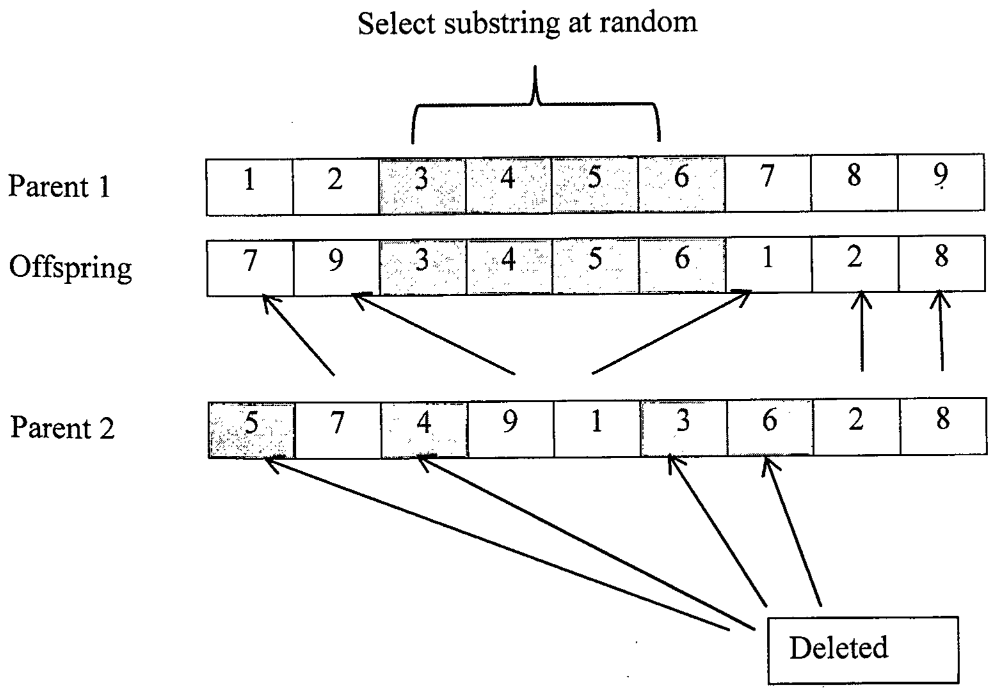
Order Crossover (OX): proposed by Davis (1985)

Step 1: select a substring from a parent at random

Step 2: produce a proto-child by copying the substring into the corresponding position of it

Step 3: delete the cities which are already in the substring from the second parent

Step 4: place the cities into the unfixed positions of proto-child from left to right according to the order of the sequence to produce an offspring



Cycle Crossover (CX): proposed by Oliver, Smith and Holland (1987)

Step 1: find the cycle which has defined the corresponding position of cities between parents.

Step 2: copy the cities in the cycle to a child with the corresponding positions of one parent

Step 3: determine the remaining cities from the child by deleting those cities which already in the cycle from the other parent

Step 4: fulfill the child with the remaining cities

1. Fined the cycle defined by parent

Parent 1	1	2	3	4	5	6	7	8	9
Parent 2	5	4	6	9	2	3	7	8	1

Cycle $1 \rightarrow 5 \rightarrow 2 \rightarrow 4 \rightarrow 9 \rightarrow 1$

2. Copy the cities in the cycle to a child

Proto-child	1	2		4	5				9

3. Determine the cities in the cycle to a child

Parent 2	5	4	6	9	2	3	7	8	1

The remaining cities

6	3	7	8

4. Fulfill the child

Offspring

1	2	6	4	5	3	7	8	9

2.5 MUTATION

Mutation represents a change in the gene. It may lead to significant improvement in fitness of the chromosomes. Holland introduced mutation as a background operator (1975). Its role is to provide a guarantee that the search algorithm is not trapped in a local optimum. A new offspring can be achieved by different ways either by flipping, inserting, swapping or sliding the allele values at two randomly chosen gene positions.

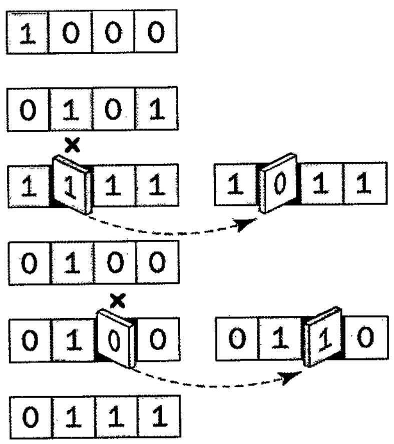


Figure 2.3 basic mutation