TRAVELING SALESMAN PROBLEM APPROACH FOR SOLVING DRUG DISTRIBUTION USING SIMULATED ANNEALING AND TABU SEARCH

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DEDICATION

To my ever-loving parents, siblings, and Dr. Dominique Gormand.

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ABSTRACT

In combinatorial mathematics and operational research, the traveling salesman problem is among the most studied problem which aims to find the least possible cost or distance when visiting all the cities exactly once. This research analyzes a drug distribution problem, which is regarded as an application of the traveling salesman problem. Two meta-heuristic methods were utilized to generate the best solution, which are the simulated annealing and tabu search. There are essential parameters for both of the methods. In the simulated annealing, the right setting for the cooling schedule is very important so that the algorithm will converge to a near-optimal solution. Moreover, the size of the tabu list is an essential value for the tabu search method since it will determine how the algorithm will search for better solutions in the search space. The results of this experiment were analyzed based on the output generated by the developed C++ program, and it revealed that the simulated annealing and tabu search methods were capable of generating a best solution within a short computational time.

ABSTRAK

Dalam matematik berkombinatorik dan penyelidikan operasi, *traveling salesman problem* adalah di antara masalah yang paling banyak dikaji. Kajian ini bertujuan untuk mengurangkan sebaik mungkin kos atau jarak untuk melawat kesemua lokasi. Kajian ini mengambil masalah pengagihan ubat ke beberapa farmasi sebagai satu aplikasi daripada masalah *traveling salesman problem*. Dua kaedah metaheuristik digunakan bagi mendapatkan penyelesaian yang optimum, iaitu *Simulated Annealing* dan *Tabu Search*. Terdapat beberapa parameter penting untuk kedua-dua kaedah ini. Dalam kaedah *Simulated Annealing*, tetapan yang betul untuk penjadualan penyejukkan adalah amat penting agar algoritma itu menumpu kepada penyelesaian yang optimum. Bagi Tabu Search pula, saiz senarai tabu adalah nilai yang penting kerana ia akan menentukan bagaimana algoritma itu mencari penyelesaian yang lebih baik di ruang carian. Hasil eksperimen ini dianalisis berdasarkan daripada output yang diperolehi dari simulasi yang dibangunkan dengan menggunakan perisian Microsoft Visual C++ dan ia menunjukkan bahawa kaedah *Simulated Annealing* dan *Tabu Search* mampu menjanakan penyelesaian optimal global dalam masa pengiraan yang singkat.

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LIST OF ABBREVIATIONS

SA	-	Simulated Annealing
TL	-	Tabu List
TS	-	Tabu Search
TSP	-	Traveling Salesman Problem

LIST OF SYMBOLS

E	-	Edges
n	-	Number of pharmacy outlets (or cities)
P	-	Probability of acceptance
V	-	Vertex
α	-	Cooling schedule
Δf	-	Difference of new solution and current solution
T_c	-	Current temperature
T_{C-1}	-	Previous temperature

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

With the trend of current globalization, major logistics challenges were introduced to organize movements across large distances. Supply chain management is all about providing the right quantity of the right product, to the right place, and at the right time. Supply chain management is of utmost importance for the healthcare and other business industries. Logistics is an important sector in the supply chain department, since it is responsible for satisfying the demands of customers. It is significant for companies such as the logistics service providers, to design an effective distribution structure, using transport and distribution centres in an optimal configuration. These plans are essential so that the challenge of transporting the right product, at the right location, and at the right time will be achieved. This is particularly true for the healthcare industry since time management is very crucial in times of emergencies.

Many developing countries are confronted with problems, such as how to reduce economic costs. The shifting of oil prices is one of the contributing factors why these business sectors aim to minimize the cost of transportation. Also, in times of emergencies, time is a major factor that needs to be considered. Any delay could have fatal results to the patients. This is why, researchers, as well as companies with integrated logistics expertise, tend to adopt new transportation routes to counter these problems. One of the significant roles of the logistics department of a business sector involves overseeing the cost of transportation and plan a quick and reliable delivery system. They aim to figure out how to minimize the cost of transport while delivering the products as fast as possible. In operational research, one of the problems that arise, which involves the cost or distances, is the traveling salesman problem (TSP).

A previous study was done regarding drug distribution using the branch-and-bound method to determine an efficient way to distribute drugs to the customers (Ceselli, Righini, & Tresoldi, 2014). The drug distribution is categorized under TSP where it involved distribution centres and vehicles. The researchers provided that although the branch-and-bound method was able to generate a good solution to the drug distribution, a further exploration of reliable specialized heuristics can be furthered. Other studies which applied tabu search to solve TSP (Basu, Sharma, & Ghosh, 2017; Gangadevi, 2018; Gong, Pan, Song, Tang, & Zhang, 2015; Rashid Khan & Asadujjaman, 2016) and vehicle routing problem (Berbotto, García, & Nogales, 2014; Zhang, Chaovalitwongse, & Zhang, 2014), has proven the TS method to generate a near optimal solution to their problem. On the other hand, the performance of simulated annealing (SA) method was explored by different researchers to generate a good solution of a TSP (Alameen, Abdul-Niby, Salhieh, & Radhi, 2016; Mukhairez & Maghari, 2015; Zhou et al., 2018). In this research, it introduces the implementation of the TSP to solve a distribution problem of medicines to different pharmaceutical outlets through utilizing the SA and TS algorithms. In this TSP, it considered that the delivery vehicle must go back to the depot, after the successful delivery of medicines to all clients.

1.2 The Traveling Salesman Problem

In computational mathematics, one of the topics which are usually studied is the traveling salesman problem. A TSP is understood that given a n number of cities, a salesman must visit each of these cities exactly once. The aim of the salesman is to select the order of cities he will travel that will give him the shortest possible total distance. Represented by a graph $G = (V, E)$, where V are the vertices, and E are the edges of a graph. In a TSP, the cities are represented as the vertices while the edges are the distances that directly connect each city.

The computational difficulty of the traveling salesman problem is rapidly enlarged as the number of cities increase. However, with the advancement of a computer's speed and memory, within a short computational time, a best solution for a traveling salesman problems can be achieved.

There are two kinds of TSP, which are the symmetric and asymmetric TSP. In this study, the symmetric TSP is considered, where it involves an equal distances of the nodes (or cities) from one city to another, only one salesman is involved, and the problem is to figure out the least possible ways that visit respective city exactly once and go back to the original starting city.

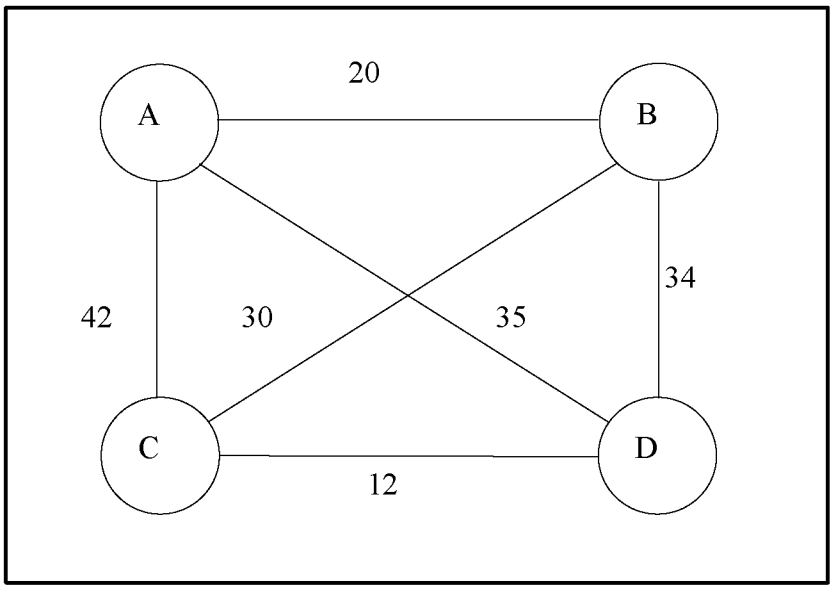

Figure 1.1 An illustration of a graph of symmetric TSP with four cities.

Figure 1.1 shows the possible routes for the salesman to take in visiting each of the cities given the distance from one city to the other, in a symmetric TSP (Mijwel, 2017). The primary objective of the traveling salesman is to choose a route or path that needs to take to visit each city which minimizes the cost. An additional condition is that, the salesman must visit the cities only one time before he returns to his starting point.

Previous researchers incorporated different meta-heuristic methods, which were proven to generate best solutions in solving optimization problems. Among these meta-heuristic methods includes the simulated annealing and tabu search. The reasons why these methods were able to generate nearly-optimal solutions were because of their unique characteristics of diversification and exploitation capabilities (I. Ismail & Halim, 2017). Hence, in this study, it aims to investigate the simulated annealing and tabu search methods to solve this symmetric traveling salesman problem in achieving better performance in optimizing the shortest distance in the delivery of the ordered pharmaceutical products.

1.3 Problem Statement

The growth in vehicle production, shifting of oil prices, as well as the need to minimize costs in traveling, have stirred the interest of researchers to optimize the travel or journey of sales personnel, daily deliveries, and transport plans. In addition, during emergencies where a certain medicine is urgently needed, the transport needs to take the route that will enable him to deliver the ordered products in a time efficient way. In the field of customer service and distribution networks, traveling salesman problem is necessary because, through its application, the services are enhanced in these industries by lessening the cost and time of navigation. The enhancement of technology made it possible for researchers to solve the traveling salesman problem within a reasonable time frame. Figure 1.2 shows a sample of one possible route of delivery.

In this research, an experiment was conducted with one international company based abroad in charge of drug distribution. The company has its own logistics department which is responsible for delivering medicines from the warehouse to different pharmacy outlets, including hospitals, in one region. A prototype study is conducted on the single transport delivery to twenty-five outlets.

In this traveling salesman problem, the transport represents the traveling salesman while the pharmacy outlets represent the cities A, B, C, D, E, and F. It is given that the starting point (depot) is predefined, and the transport will finish its track at the point of origin.

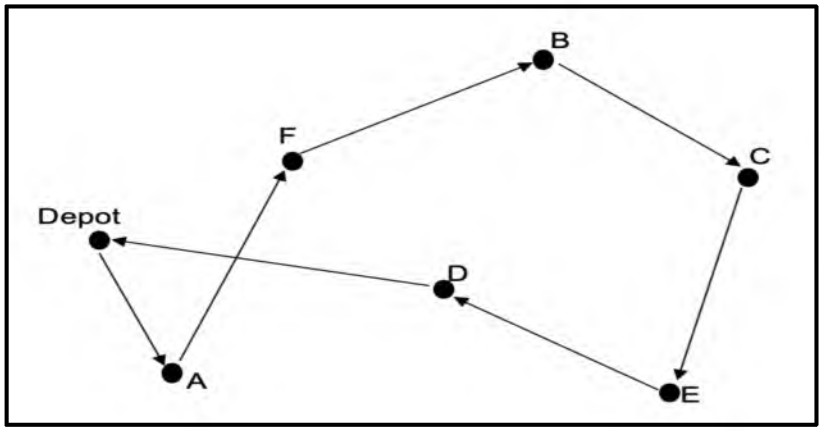

Figure 1.2 Shows a possible route of the transport for the delivery of medicines.

1.4 Objectives of the research

The objectives of the research are:

(a) Generate a best solution for the traveling salesman problem through the implementation of simulated annealing and tabu search.

(b) To design and develop a prototype C++ program to generate possible routes for the traveling salesman problem;

1.5 Scope of the research

This research is purposely done to solve a TSP with twenty-five pharmaceutical outlets abroad. The data used for this study were simulated based on the location of different pharmaceutical outlets in the map. These data will be utilized to identify the best route possible that will give the least reasonable cost for the logistics company, applying the simulated annealing and tabu search methods. Microsoft Visual 2019 is maximized to write the C++ codes to solve this traveling salesman problem.

1.6 Significance of the research

In the search for the shortest distance to deliver the medical products to the different pharmaceutical outlets, this research will provide the best route that will minimize the cost of the transportation. The solutions derived from this study can also be used for further studies about TSP and another optimization problem. The result of this study will also determine the best route in delivering the pharmacy products, which in turn, will benefit the logistics company in reducing the cost of transport. Moreover, the application of simulated annealing and tabu search and the utilization of the C++ program will provide information for future researchers about how these methods are reliable in generating solutions for the traveling salesman problem.

1.7 Thesis Outline

This dissertation comprises of five chapters. The first section of the study talks about the introduction, statement of the problem, objectives of the research, scope, and significance of this study conducted.

The second chapter of this study is the literature review, where it presents the literary studies and experiments conducted by previous researchers, which are related to the topic. It also includes the application of graph theory, which is the base of this research, the traveling salesman problem. Furthermore, it presents the two meta-heuristic methods chosen to solve the problem, the simulated annealing, and tabu search.

Chapter three elaborates on how the chosen meta-heuristics will be utilized to solve the problem. The parameters used will be thoroughly discussed in this segment. All of the computations, the codes used to write, and develop the C++ program, the experiments conducted, and the results will be presented in the fourth chapter. The last section of this research will summarize the results gathered and give recommendations for further study.

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