

**HYBRID GENETIC ANT COLONY OPTIMISATION TECHNIQUE FOR
TRAVELLING SALESMAN PROBLEM**

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**HYBRID GENETIC ANT COLONY OPTIMISATION TECHNIQUE FOR
TRAVELLING SALESMAN PROBLEM**

TEO CHIA LEE

The report is submitted in partial fulfillment of the requirements for the Bachelor
of Computer Science (Artificial Intelligence)

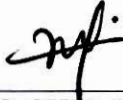
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2011

DECLARATION

I hereby declare that this project report entitled
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TRAVELLING SALESMAN PROBLEM**

is written by me and is my own effort and that no part has been plagiarized
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STUDENT :  _____ Date: 15/7/2011
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DEDICATION

To my dearest parents, Mr. Teo Leong Kim and Mrs. Ho Yoke Ling, for their touching caring and fully support.

To my supervisor, Dr. Choo Yun Huoy, for making this project worthy.

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ABSTRACT

Ant Colony Optimization (ACO) algorithm is a famous optimization technique that using artificial ant agents to generate solutions for Travelling Salesman Problem (TSP) by mimic real ant behavior in finding source of food. However, ACO may generate an inefficiency travelling path caused by premature convergence to local optimum. The larger the data size, the higher the probability of ACO converges premature into local optimum. This project proposes a hybrid technique, the Genetic Ant Colony Optimization (GACO) technique to overcome the problem. Due to the stochastic characteristics of Genetic Algorithm (GA), it is able to prevent ACO premature convergence to local optimum effectively by hybridized it with ACO. In order to evaluate the performance of GACO, a module of GACO has been designed and implemented. Thus, a comparison of performance between ACO and GACO has been conducted by applying both of the techniques to three typical TSP which are lau15, kn57 and sgb128. Measurement parameters involve in the comparison are best distance, averaged distance and error percentage. Results generated by ACO and GACO have been analyze and finally come out with a conclusion which is GACO perform better than ACO in solving all of the problems. Finally, GACO has been embedded into Intelligent Vacation Planner System (IVPS). IVPS is a web application that applying ACO as its optimization technique to solve the travelling problem of tourist. IVPS is able to generate travelling route with minimum distance that based on travel spots selected by tourist. However, IPVS may generate inefficient travelling path in sometimes especially for large number of travel spots. By replacing ACO with GACO, IVPS is able to generate efficient travelling path even for large number of travel spots.

ABSTRAK

Ant Colony Optimization (ACO) adalah teknik pengoptimuman yang mengguna ejen semut pintar yang dapat meniru tingkah laku semut sebenar dalam mencari sumber makanan untuk menjanakan penyelesaian bagi Travelling Salesman Problem (TSP). Tetapi, ACO mungkin menjanakan laluan perjalanan cuti yang tidak cekap. Ini adalah kerana ACO menumpu terlalu awal ke dalam optimum tempatan. Semakin banyak bilangan tempat pelancongan yang perlu disusun dalam perjalanan, semakin tingginya kebarangkalian ACO menumpu ke optimum tempatan. Projek ini telah mencadangkan teknik hybrid, Genetic Ant Colony Optimization (GACO) untuk mengatasi masalah ini. Oleh kerana ciri-ciri stokastik daripada Genetic Algorithm (GA) mampu menghalang ACO menumpu terlalu awal ke dalam optimum tempatan secara berkesan dengan mensilangkan ACO dengan GA. Untuk menilai prestasi GACO, modul GACO telah direka bentuk dan dibina. Perbandingan prestasi telah diadakan antara ACO dan GACO. Kedua-dua teknik telah diggunakan untuk menyelesaikan 3 masalah TSP iaitu Lau15, Kn57 dan Sgb128. Parameter-parameter pengukuran yang terlibat dalam perbandingan adalah jarak terbaik, purata jarak, dan peratusan silap. Keputusan yang dihasil oleh pihak ACO dan GACO telah dianalisis. Kesimpulan akhirnya menyatakan GACO adalah lebih baik daripada ACO dalam menyelesaikan ketiga-tiga masalah. Akhirnya, GACO telah dimasukkan ke dalam Intelligent Vacation Planner System (IVPS). IVPS ialah sebuah aplikasi web yang menggunakan ACO untuk menyelesaikan masalah laluan bagi pelancong. IVPS mampu menjana laluan perjalanan yang mempunyai jarak yang minimum berdasarkan tempat-tempat pelancongan yang dipilih oleh pelancong. Walau bagaimanapun, IVPS kadang-kadang akan menjanakan laluan perjalanan yang tidak cekap terutama bagi kumpulan tempat-tempat pelancongan yang besar. Dengan menggantikan ACO dengan GACO, IVPS dapat menjanakan laluan perjalanan yang cekap walaupun bagi kumpulan tempat-tempat pelancongan yang besar.

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LIST OF ABBREVIATIONS

AI	-	Artificial Intelligent
TSP	-	Travelling Salesman Problem
ACO	-	Ant Colony Optimization
IVPS	-	Intelligent Vacation Planner System
GA	-	Genetic Algorithm
GACO	-	Genetic Ant Colony Optimization
SA	-	Simulated Annealing
PSO	-	Particle Swarm Optimization
BA	-	Bee Algorithm
NP	-	Nondeterministic Polynomial
P	-	Polynomial-time solvable
AS	-	Ant System
ACS	-	Ant Colony System
PMX	-	Partial Mapped Crossover Operator
ES	-	Evolution Strategy

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CHAPTER I

INTRODUCTION

1.1 Project Background

There are a lot of Artificial Intelligent (AI) optimization techniques have been deployed nowadays to solve real-world problems. One typical type of real world problem is combinatorial optimization problem. Combinatorial optimization problem is type of problem that searching for the best solution from a set of feasible solutions. Example of famous combinatorial optimization problem are Traveling Salesman Problem (TSP), Clique, Graph coloring, Vertex Cover, Bin Packing, Partition and etc.

TSP is one of the famous combinatorial optimization problems that belong to NP-complete class. It is a problem of finding a shortest travelling path for a given set of cities with known distance value between each pair of cities. And the path must visit each city exactly once. There are a lot of effective heuristic method have been introduced to solve this problem such as Simulated Annealing, Genetic Algorithm, Tabu-Search, Particle Swarm Optimization and Ant Colony optimization (ACO).

ACO algorithm is a famous optimization technique in solving combinatorial optimization problem such as TSP. This optimization technique using artificial ant agents to generate solutions of visiting sequence by mimic real ant behavior in finding source of food. An ant agent is able to make decision in choosing the next destinations to be visit between travelling spots and thus conduct a travelling path as

solution. So ACO has been applied in Intelligent Vacation Planner System (IVPS) to generate the optimum travel path for tourists.

IVPS is an intelligent web application which is able to generate an optimum travelling path for vacation based on tourist's preferences. Tourists will select the travelling spots which they are going to visit in their vacation and IVPS will generate an optimum travelling sequence for those vacation spots in order to help tourists saving their time and money. Generation of an optimum travelling path for vacation is an enhancement version of TSP.

However, there is a weakness in ACO which is premature convergence. This weakness will seriously affect the quality of solutions generated by ACO in certain situations. In order to solve the weakness, a hybrid algorithm of ACO and Genetic Algorithm (GA) has been introduced which is Genetic Ant Colony Optimization (GACO).

1.2 Problem Statement

Main problem of this project is ACO optimization technique having a weakness which is convergence to local optimum prematurely that may cause ACO fail to generate efficiency travelling path. Probability of premature convergence of ACO into local optimum is directly proportional to the number of travel spots. The larger the number of travel spots that need to be scheduled into an optimum path, the higher the probability of ACO premature convergence into local optimum. Once the ACO prematurely converges to local optimum, travelling path generated by ACO will not be the optimum solutions. Consequently, ACO may not generate an efficiency optimum travelling path for large number of travel nodes set.

1.3 Objective

Objective of this project are as following:

- To propose a hybrid Genetic Ant Colony Optimization (GACO) algorithm to prevent premature convergence in Ant Colony Optimization (ACO) algorithm for solving Travelling Salesman Problem (TSP).
- To design and implement the GACO algorithm.
- To compare and evaluate the GACO algorithm against ACO algorithm.
- To embed GACO algorithm in Intelligent Vacation Planner System (IVPS).

1.4 Scope

This project is mainly concern in finding a suitable technique to prevent the premature converge problem of ACO when solving combinatorial optimization TSP problem. Type of TSP problem mentioned in this project is symmetric TSP problem. 3 dataset of TSP problem being use in the experiment of this project are Lau15, Kn57 and Sgb128. Range of number of nodes cover in this project is from 15 nodes to 128 nodes. Lau15 is consider as small scale problem and Kn57 is consider as middle scale problem while Sgb128 is consider as large scale problem in this project. Measurement parameters of this project are best distance, averaged distance and error percentage. Based on these measurement parameters, a conclusion will be state, whether the GACO able to gain better performance than ACO. Computational time is not including in the performance measurement.

1.5 Project Significance

This project may benefit researcher in related field by providing the effective method to solve the premature convergence problem of ACO. Besides, this project also help tourist that using IVPS in planning schedule of their vacation, they are able

to scheduling an optimum travelling path even though with larger number of travelling spots included.

1.6 Expected Output

The expected output for this project is the comparison result of GACO and ACO algorithm in solving 3 different routing problems. Another output of this project is an application of GACO algorithm which is implemented in java programming language that can be used to solve routing problem. Besides, an IVPS that embedded GACO algorithm as its optimization technique is also one of the outputs of this project.

1.7 Conclusion

This project is developed to solve the premature convergence weakness of ACO algorithm. A hybrid algorithm of ACO algorithm and GA algorithm, GACO has been proposed to prevent the ACO convergence to local optimal solution prematurely especially in solving large scale TSP problem. In order to solve the problem, application of ACO and GACO will be implemented. Experiments will be conducted to test the performance of ACO and GACO in solving three TSP problems with different scales. Then, an analysis will be carried out towards the experimental results generated by ACO and GACO. Finally, a conclusion will be drawn regarding whether the objective of the project has been achieved. After that, if GACO is performing better than ACO, GACO algorithm will replace ACO algorithm to be the optimization technique of IVPS in order to increase the performance of IVPS.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Literature review related to the history and background of combinatorial optimization problem, Travelling Salesman Problem (TSP) and Ant Colony Optimization (ACO) has been conducted for deeper understanding. Besides, literature review also has been done in finding AI optimization techniques that are able to deal with weakness of ACO algorithm. Genetic Algorithm (GA), Simulated Annealing (SA), Particle Swarm Optimization (PSO) and Bee Algorithm (BA) have been shortlisted. Although the literature will presents these techniques in variety of contents, this review will mainly focus on their strengths and drawbacks in preventing ACO algorithm premature converge to local optimal. By listing of these techniques, a comparison has been conducted to find out the most suitable technique to solve the weakness of ACO algorithm.

2.2 Combinatorial Optimization Problem

Combinatorial optimization problem is problem that focuses on finding a best solution from a set of feasible solutions in a finite space. Such solution is called an optimum solution where the desired extreme output value of problem's objective function is attained under a number of boundary or constraint conditions. Output

value of objective function can either be maximum or minimum, depend on the problem requirement (Souza, 2011).

Mathematicians have been studying combinatorial optimization problems since 19 century, an early book on the subject is *Combinatorial Optimization: Networks and Matroids* from 1976 (Lawler, 1976). Two essential topics of the early history of combinatorial optimization are network flow and linear programming. Ford and Fulkerson in 1950s had proved that network flow is a discrete combinatorial optimization problem (Ford and Fulkerson, 1956), while linear programming problem also had been proved as a discrete combinatorial optimization problem by Dantzig and Von Neumann (Dantzig, 1963).

In 1965, Jack Edmonds had advocated an idea where a method can be said as efficient if it is required only polynomial time to solve the combinatorial optimization problem (Edmonds, 1965). Polynomial time is running time of method used to solve combinatorial problem, which is bounded by a polynomial in the size of representation. Since then, this criterion has been widely accepted. It is because Edmonds has found polynomial-time method for several important combinatorial optimization problems such as matching problem. Besides, Edmonds has discovered also several problems that do not have polynomial-time method to solve it such as Hamiltonian paths.

In 1970s, Stephen Cook and Richard Karp listed many combinatorial optimization problems such as clique, graph coloring, vertex cover, travelling salesman problem, bin packing and partition and proved that all these problems are belong to class nondeterministic polynomial (NP) which is the hardest in a large natural class of problems (Cook, 1971, Karp, 1972). NP class is the class of problems recognizable in nondeterministic polynomial time. Any problem in NP class can be reduced to NP-complete problems. NP-complete problems are equivalent in the sense that the polynomial-time solvability of one of them implies the same for all of them. From then until now, almost every combinatorial optimization problem has been either proved to be polynomial-time solvable (P) or NP-complete (class NP). However, none of the problems have been proved to be both.

This project is focus on travelling salesman problem (TSP) which is a NP-complete combinatorial optimization problem.

2.3 Travelling Salesman Problem

Travelling salesman problem (TSP) can be simply explain as a combinatorial optimization problem that focus on discover of an optimum path that visits every cities exactly once for a given set of cities with knowing distance between cities. Optimum path is a visiting sequence of cities with minimum total travel distance. In terms of graph theoretic, TSP problem is a problem of finding a Hamiltonian circuit contains minimum total cost for a given undirected graph with a cost for each edge of the graph.

Similar ideas of TSP have been discovered for a long time such as seven bridges round trip in Konigsberg (1736), handbook for German travelling salesman (1832) and Icosian Game marketed by William Rowan Hamilton (1857). However, first studied of general form of TSP was conducted by Karl Menger and his colleague during 1930s in Vienna and Harvard where Menger asked for a shortest Hamilton path that go through several given points and his was aware of the complexity of TSP. After that, Hassler Whitney called the problem as TSP in one of his seminar talk at Princeton University in late 1930s.

In the middle of 1940s, some papers that study the TSP appeared and these papers seem to be the first mathematical results of the problem. In 1940, Menger returned his research to the question of shortest path go through a given set of points in a metric space (Menger, 1940). After that, Milgram has conducted investigations in the same year on the shortest Jordan curve that included a given set of points in a metric space that may not necessary be finite (Milgram, 1940). Besides of that, Fejes also studied the problem of shortest curve that covers n points in the unit square in year 1940 (Fejes, 1940).

In the late of 1940s and early of 1950s, TSP was studied intensively by researchers at the RAND Corporation in Santa Monica California. In 1949, Julia Robinson who had failed in solving TSP has mentioned in a RAND Report that she

had found a relation where the assignment problem asks for an optimum permutation meanwhile the TSP asks for an optimum cyclic permutation (Robinson, 1949). And thus, Beckmann and Koopmans have noticed that the TSP can be formulated as a quadratic assignment problem in year 1952 (Beckmann and Koopmans, 1952). In addition, a seminal paper of fundamental progress of TSP was made in 1954 by the researchers of RAND, who are Dantzig, Fulkerson and Johnson. This paper introduced some new methods to solve the TSP which are now basic in the combinatorial optimization problem (Dantzig *et al.*, 1954). Besides, this paper also shows the importance of cutting planes method for combinatorial optimization problem. In addition, other works on TSP in 1950s was done by Morton and Land (1955), Barachet (1957), Croes (1958), Rossman and Twery (1958), and Bock (1958). Furthermore, Dantzig, Fulkerson and Johnson had proved that their method successfully generates the optimality of Barachet's solution in 1959 (Dantzig *et al.*, 1959).

Along of 1950s and 1960s, outstanding progress was achieved on other combinatorial optimization problems such as transportation problem, assignment problem, maximum flow problem, minimum spanning tree problem and matching problem. However, there is no obviously progress in TSP. TSP has not yet been solved around these years. In 1972, Karp has proved that TSP is an NP-complete problem (Karp, 1972). All of the exact methods for TSP cost exponential time to solve it. No method able to solve TSP while spending only polynomial time.

But the good news is there are a lot of effective heuristics have been developed in order to find the solution of TSP with acceptable quality in polynomial time. Examples of heuristic are simulated annealing, genetic algorithm, particle swarm optimization and ant colony optimization and etc. Simulated annealing was introduced by Kirkpatrick from annealing process (Kirkpatrick *et al.*, 1983). It has been applied to solve TSP problem by Malek (Malek *et al.*, 1989) and Johnson (Johnson and McGeoch, 1995). Genetic algorithm was introduced by Holland (Holland, 1975), it is inspired by evolutionary process in natural. It has been applied to TSP by Larranaga in 1999 (Larrañaga *et al.*, 1999), Grefenstette in 1996 (Grefenstette, 1996) and Khan in 2009 (Khan *et al.*, 2009). Particle swarm optimization was introduced by Eberhart and Kennedy, inspired from the social