



UNIVERSITI PUTRA MALAYSIA

**ANT SYSTEM WITH HEURISTICS FOR
CAPACITATED VEHICLE ROUTING PROBLEM**

TAN WEN FANG

IPM 2013 1

**ANT SYSTEM WITH HEURISTICS FOR
CAPACITATED VEHICLE ROUTING PROBLEM**



TAN WEN FANG

**MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA**

2013

**ANT SYSTEM WITH HEURISTICS FOR
CAPACITATED VEHICLE ROUTING PROBLEM**



By

TAN WEN FANG

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfillment of the Requirements for the Degree of Master of Science**

January 2013

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfillment of the requirement for the degree of Master of Science

**ANT SYSTEM WITH HEURISTICS FOR
CAPACITATED VEHICLE ROUTING PROBLEM**

By

TAN WEN FANG

January 2013

Chairman: Lee Lai Soon, PhD

Faculty: Institute for Mathematical Research

Capacitated Vehicle Routing Problem (CVRP) involves the design of a set of minimum cost routes, starting and ending at a single depot, for a fleet of vehicles to service a number of customers with known demands. It is a basic production and distribution management problem which is of economic importance to business because of time and costs contributed by the delivery of the products from the depot to the customers.

The aim of this research is to develop an Ant Colony Optimization (ACO) for solving the CVRP where it simulates the behavior of real ants that always find the shortest path between their nest and a food source through an indirect form of communication, namely pheromone trail. Specifically, the proposed methodology in this study is called Ant System with Heuristics (ASH) and it was developed based on the first ACO metaheuristic, known as Ant System (AS). The ASH algorithm is basically applied with its probabilistic decision rule and pheromone feedback to

construct the sequences of customers to be visited in the CVRP solution. Meanwhile, modification was made on the evaporation procedure during the pheromone update process. As a route improvement strategy, two heuristics which are the swap among routes procedure and 3-opt algorithm are also employed within the ASH algorithm.

Preliminary computational experiments testing on a range of benchmark data set were conducted to find the appropriate set of parameters for the developed ASH. Finally, the proposed ASH was tested on two well known benchmark data sets to evaluate its performance and effectiveness. The computational results suggest that the AS approach embedded with heuristic(s) outperforms the pure AS algorithm. In addition, the proposed ASH approach was shown to be comparable with other metaheuristics especially in terms of computation time but it performed weaker at solving larger CVRP. As a result, the ASH algorithm is a viable alternative for addressing the CVRP with satisfactory solution quality and run time.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Sarjana Sains

**SISTEM SEMUT DENGAN HEURISTIK BAGI
MASALAH PENGHALAAN KENDERAAN BERMUATAN**

Oleh

TAN WEN FANG

Januari 2013

Pengerusi: Lee Lai Soon, PhD

Fakulti: Institut Penyelidikan Matematik

Masalah penghalaan kenderaan bermuatan (CVRP) melibatkan reka bentuk satu set laluan yang mempunyai kos minimum, bermula dari dan berakhir di satu gudang, bagi satu barisan kenderaan untuk memberi khidmat kepada suatu bilangan pelanggan yang diketahui permintaannya. Masalah ini merupakan masalah asas bagi pengurusan pengeluaran and pengedaran yang berkepentingan ekonomi kepada perniagaan disebabkan oleh masa dan kos yang disumbangkan oleh penghantaran produk dari gudang ke destinasi para pelanggan.

Tujuan penyelidikan ini adalah untuk mengembangkan pengoptimuman koloni semut (ACO) bagi menyelesaikan CVRP di mana pendekatan ini mensimulasikan tingkah laku semut dalam kehidupan sebenar yang selalu mencari laluan terpendek di antara sarang mereka dengan sesuatu lokasi sumber makanan melalui satu bentuk komunikasi secara tidak langsung, iaitu jejak feromon. Secara terperinci, metodologi yang dicadangkan dalam kajian ini dipanggil sistem semut dengan heuristik (ASH)

dan pendekatan ini telah dibangun berdasarkan metaheuristik ACO pertama yang dikenali sebagai sistem semut (AS). Algoritma ASH pada asasnya digunakan bersama dengan peraturan keputusan kebarangkaliannya dan maklum balas feromonnya untuk membina jujukan pelanggan yang akan dilawati dalam penyelesaian CVRP. Sementara itu, pengubahsuaian telah dibuat ke atas prosedur penyejatan dalam proses pengemaskinian feromon. Sebagai satu strategi pembaikan laluan, dua heuristik iaitu prosedur tukarganti antara laluan dan algoritma 3-opt juga dilaksanakan dalam algoritma ASH.

Ujikaji berkomputasi peringkat awal dengan ujian ke atas satu lingkungan set data tanda aras telah dijalankan untuk mencari satu set parameter yang sesuai bagi ASH yang dibangunkan. Akhirnya, ASH yang dicadangkan telah diuji ke atas dua set data tanda aras yang diketahui umum untuk menilai prestasinya dan juga keberkesanannya. Keputusan pengiraan mencadangkan bahawa pendekatan AS dengan heuristik mengatasi prestasi algoritma AS tulen. Di samping itu, pendekatan ASH yang dicadangkan telah ditunjukkan setanding dengan pelbagai metaheuristik lain terutamanya dari segi masa pengiraan tetapi ASH berprestasi lebih lemah dalam menyelesaikan CVRP yang bersaiz besar. Kesimpulannya, algoritma ASH adalah satu alternatif berdaya maju yang boleh menangani CVRP dengan penyelesaian berkualiti dan masa pengiraan yang memuaskan.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank and express my gratitude to my supervisor, Assoc. Prof. Dr. Lee Lai Soon, from the bottom of my heart for his guidance, encouragement, patience and support throughout the journey of this research. He has indeed given me a lot of valuable suggestions and advices towards the completion of my study and also did a careful checking on my thesis.

In addition, my appreciation goes to Prof. Dr. Habshah Midi and Assoc. Prof. Dr. Zanariah Abdul Majid for willing to be part of my supervisory committee members and for their assistance throughout the period of my study. Apart from that, I would like to express my thanks to all teachers and lecturers who had taught me formerly.

Last but not least, I would like to give my special thanks and appreciation to my beloved family members who have always been there for me. Their love and caring have encouraged me to move forward all the time. My gratitude also goes to my dearest friends for their encouragement and support throughout the period of this degree. No word can adequately express my sincere appreciation at this moment.

I certify that a Thesis Examination Committee has met on 21 January 2013 to conduct the final examination of Tan Wen Fang on her thesis entitled “Ant System with Heuristics for Capacitated Vehicle Routing Problem” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Mohd Rizam bin Abu Bakar, PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Norihan binti Md Arifin, PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Leong Wah June, PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Ismail bin Mohd, PhD

Professor
Faculty of Science and Technology
Universiti Malaysia Terengganu
(External Examiner)

SEOW HENG FONG, PhD

Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 21 March 2013

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Lee Lai Soon, PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Habshah binti Midi, PhD

Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

Zanariah binti Abdul Majid, PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD

Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

TAN WEN FANG

Date: 21 January 2013

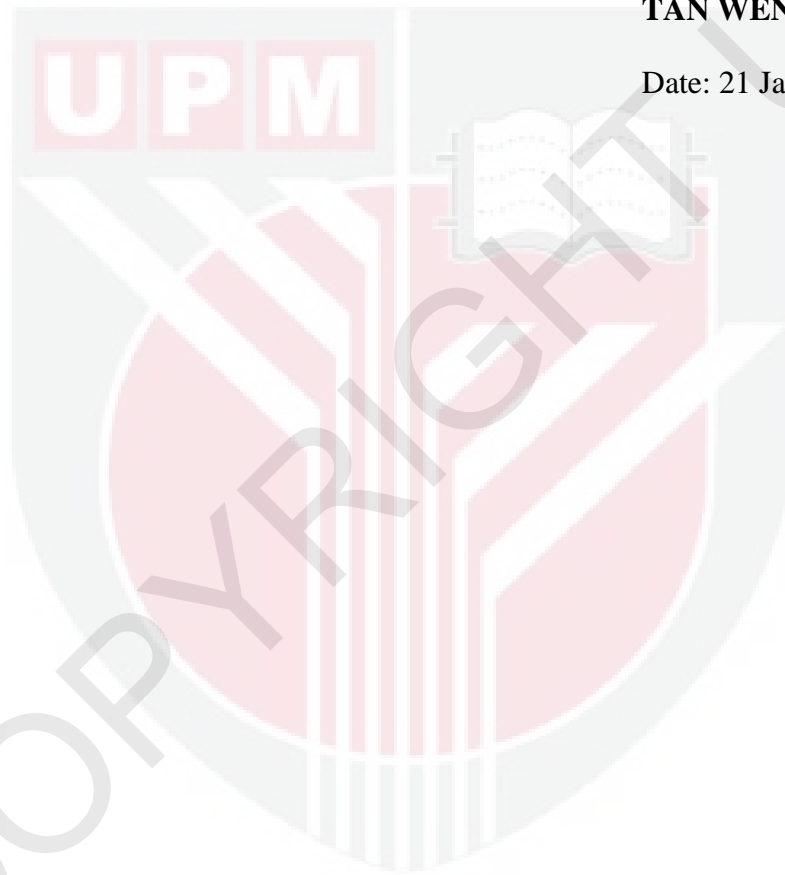


TABLE OF CONTENTS

		Page
	ABSTRACT	ii
	ABSTRAK	iv
	ACKNOWLEDGEMENTS	vi
	APPROVAL	vii
	DECLARATION	ix
	LIST OF TABLES	xii
	LIST OF FIGURES	xv
	LIST OF ABBREVIATIONS	xvi
	CHAPTER	
1	INTRODUCTION	1
	1.1 Background	1
	1.2 Problem Statement	3
	1.3 Scope and Limitation	6
	1.4 Objectives of the Thesis	7
	1.5 Overview of the Thesis	8
2	RESEARCH BACKGROUND AND LITERATURE REVIEW	10
	2.1 Introduction	10
	2.2 Vehicle Routing Problem	10
	2.2.1 Heuristic Approaches for VRP	13
	2.2.2 Metaheuristic Approaches for VRP	30
	2.3 Ant Colony Optimization	41
	2.3.1 The ACO Metaheuristic	42
	2.3.2 ACO for VRP	50
	2.4 Summary	57
3	METHODOLOGY	60
	3.1 Introduction	60
	3.2 Ant System with Heuristics	60
	3.2.1 Solution Construction	62
	3.2.2 Heuristics	67
	3.2.3 Pheromone Update	70
	3.3 Summary	73
4	RESULTS AND DISCUSSION	75
	4.1 Introduction	75
	4.2 Benchmark Data Set	75
	4.2.1 Christofides Instances	76
	4.2.2 Taillard Instances	77
	4.3 Parameters Setting and Experimental Design	79
	4.4 Experimental Results	81
	4.4.1 Initial Investigation	81
	4.4.2 Comprehensive Experiment	107

4.5	Discussion	124
5	CONCLUSION AND FUTURE RESEARCH	127
5.1	Conclusion	127
5.2	Future Research	129
	BIBLIOGRAPHY	131
	APPENDICES	136
	BIODATA OF STUDENT	144
	LIST OF PUBLICATIONS	145

