ANT COLONY OPTIMIZATION IN DYNAMIC ENVIRONMENTS

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DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, excerpts, equations, summaries and references, which have been duly acknowledged. Any contribution made to research by others, with whom I have worked at UMS or elsewhere, is explicitly acknowledged in the thesis. I also declare that the intellectual content of this thesis is the product of my own work, except to the extent that assistance from others in the project's design and conception or in style, presentation and linguistic expression is acknowledged.

04 AUGUST 2010

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MATRIC NUMBER	**: PS05-008-026**
TITLE	**: ANT COLONY OPTIMIZATION IN DYNAMIC ENVIRONMENTS**
DEGREE	**: MASTER OF SCIENCE (SOFTWARE ENGINEERING)**
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Chen Fei Huang
4 August 2010

ABSTRACT

ANT COLONY OPTIMIZATION IN DYNAMIC ENVIRONMENTS

Optimization is the process of finding the maximum or minimum of some objective function. During recent years, a new direction of research has emerged in optimization, with the research focus moving from the conventional static optimization problems to the dynamic optimization problems. Dynamic optimization problems differ from the static ones where the optimal solution is dynamic and changes over time. A similar trend can be seen in the application of Ant Colony Optimization (ACO). ACO is an optimization technique inspired by the ants' foraging behavior which optimizes their routes taken to food sources. This thesis is an investigation into the application of ACO for solving dynamic optimization problems. The first objective of this study is to identify which ant algorithm performs the best under a dynamic environment. In order to achieve this objective, six ant algorithms namely Ant System (AS), Ant Colony System (ACS), Best-Worst Ant System (BWAS), Elitist Ant System (EAS), Max-Min Ant System (MMAS) and Rank-Based Ant System (RBAS) were implemented to solve a dynamic optimization problem in the form of the dynamic Traveling Salesman Problem (TSP). Three different sizes of the dynamic TSP test sets were used: eil51 (small), lin318 (medium) and d1291 (large). Apart from the size of the optimization problem, how the swapping interval affects the dynamic optimization by the ant algorithms is also investigated. Swapping of cities in the dynamic TSP was done in the early, middle and late stages of the optimization process. A series of 30 test runs were conducted on each dynamic TSP instance and also for each swap condition. The second objective of the research is to investigate the suitability of applying local search algorithms to the best performing ant algorithm from the first objective. For this purpose, three local search algorithms namely 2-opt, 2.5-opt and 3-opt were chosen to be coupled with the ant algorithm in order to solve the dynamic TSP. The last objective of this thesis is to optimize the parameter settings of the best performing ant algorithm with local search. From the experimental analysis, it was found that ACS works best for solving the dynamic TSP compared to the other five ant algorithms. When coupled with a local search technique, a significant improvement can be seen for ACS using the 3-opt local search algorithm. Lastly, it was also found that different optimal parameter settings were required for solving the different sizes of the dynamic TSP problems.

ABSTRAK

*Pengoptimuman merupakan satu proses pencarian maksimum atau minimum fungsi berobjektif. Sejak kebelakangan ini, suatu halatuju penyelidikan yang baru telah timbul dalam bidang pengoptimuman, di mana fokus penyelidikan telah berubah daripada masalah pengoptimuman statik kepada masalah pengoptimuman dinamik. Perbezaan di antara masalah dinamik dengan masalah statik adalah masalah dinamik mempunyai penyelesaian optimum yang dinamik dan berubah mengikut masa. Corak yang sama dapat dilihat dalam pengaplikasian "**Ant Colony Optimization**" (ACO). ACO adalah teknik pengoptimuman yang diilhamkan oleh sifat pencarian makanan semut yang mengoptimumkan penghalaan jalan-jalan mereka ke punca makanan. Tesis ini menerangkan satu penyelidikan yang dijalankan untuk mengenalpasti algoritma semut yang mempunyai pencapaian terbaik dalam keadaan dinamik. Objektif pertama penyelidikan ini ialah mengenal pasti algoritma semut yang berpencapaian terbaik di dalam keadaan dinamik. Untuk mencapai objektif ini, enam algoritma semut, iaitu "**Ant System**" (AS), "**Ant Colony System**" (ACS), "**Best-Worst Ant System**" (BWAS), "**Elitist Ant System**" (EAS), "**Max-Min Ant System**" (MMAS) dan "**Rank-Based Ant System**" (RBAS) telah dibangunkan untuk menyelesaikan masalah dinamik yang berbentuk masalah dinamik "**Traveling Salesman**" (TSP). Tiga set ujian TSP yang berlainan saiz telah digunakan: eil51 (kecil), lin318 (sederhana) dan d1291 (luas). Selain daripada saiz masalah yang berlainan, kesan masa penukaran bandar-bandar pada masa-masa berlainan ke atas pengoptimuman dinamik oleh algoritma semut juga dikaji. Penukaran bandar-bandar di dalam TSP dinamik telah dilakukan pada tahap awal, pertengahan dan akhir semasa proses pengoptimuman. Satu siri ujian yang merangkumi 30 perlaksanaan bagi setiap masalah TSP dinamik dan juga untuk setiap masa penukaran telah dijalankan. Objektif kedua penyelidikan ialah menyiasat kesesuaian penggunaan algoritma pencarian tempatan apabila diaplikasikan kepada algoritma terbaik hasil dapatan daripada objektif pertama untuk penyelesaian masalah dinamik. Untuk mencapai tujuan ini, tiga algoritma pencarian tempatan iaitu 2-opt, 2.5-opt dan 3-opt telah dipilih untuk diaplikasikan bersama algoritma semut bagi menyelesaikan TSP dinamik. Untuk objektif terakhir, penentuan parameter terbaik bagi algoritma semut bersama dengan algoritma pencarian tempatan dilaksanakan. Analisa hasil kajian menunjukkan bahawa ACS mempunyai prestasi terbaik berbanding lima algoritma yang lain dalam keadaan dinamik. Peningkatan prestasi yang ketara dapat dilihat bagi algoritma semut apabila algoritma pencarian tempatan 3-opt diaplikasikan bersama ACS. Hasil ujian daripada objektif terakhir menunjukkan penentuan parameter terbaik yang berlainan diperlukan untuk menyelesaikan dinamik TSP yang berlainan saiz.*

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LIST OF ABBREVIATIONS

ACO	Ant Colony Optimization
ACS	Ant Colony System
AS	Ant System
BWAS	Best-Worst Ant System
EAS	Elitist Ant System
MMAS	Max-Min Ant System
PSO	Particle Swarm Optimization
QAP	Quadratic Assignment Problem
RBAS	Rank-based Ant System
TSP	Traveling Salesman Problem

LIST OF SYMBOLS

α	Parameter that controls the pheromone information
β	Parameter that controls the heuristic information
d_{ij}	The distance between city *i* and city *j*
ρ	Parameter that control the evaporation rate
τ_{ij}	The pheromone information between city *i* and city *j*
η_{ij}	The heuristic information between city *i* and city *j*
$S_{global-best}$	The global-best ant

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*Optimasasi merupakan satu proses pencarian maksimum atau minimum fungsi berobjektif. Sejak kebelakangan ini, suatu halatuju penyelidikan yang baru telah bertimbul dalam bidang optimasasi, di mana focus penyelidikan telah berubah daripada masalah optimasasi 6riter kepada masalah optimasasi dinamik. Perbezaan di antara masalah dinamik dengan masalah 6riter adalah masalah dinamik mempunyai penyelesaian optima yang dinamik dan berubah mengikut masa. Corak yang sama dapat dilihat dalam pengaplikasian "**Ant Colony Optimization**" (ACO). ACO adalah teknik optimasasi yang diilhamkan oleh sifat pencarian makanan semut yang mengoptimasikan penghalaan jalan-jalan mereka ke punca makanan. Tesis ini menerangkan satu penyelidikan yang dijalankan untuk mengenalpasti algoritma semut yang mempunyai pencapaian terbaik dalam keadaan dinamik. Objektif pertama penyelidikan ini ialah mengenal pasti algoritma semut yang berpencapaian terbaik di dalam keadaan dinamik. Untuk mencapai objektif ini, enam algoritma semut, iaitu "**Ant System**" (AS), "**Ant Colony System**" (ACS), "**Best-Worst Ant System**" (BWAS), "**Elitist Ant System**" (EAS), "**Max-Min Ant System**" (MMAS) dan "**Rank-Based Ant System**" (RBAS) telah dibangunkan untuk menyelesaikan masalah dinamik yang berbentuk masalah dinamik "**Traveling Salesman**" (TSP). Tiga set ujian TSP yang berlainan saiz telah digunakan: eil51 (kecil), lin318 (sederhana) dan d1291 (luas). Selain daripada saiz masalah yang berlainan, kesan masa penukaran bandar-bandar pada masa-masa berlainan ke atas optimasasi dinamik oleh algoritma semut juga dikaji. Penukaran bandar-bandar di dalam TSP dinamik telah dilakukan pada tahap awal, pertengahan dan akhir semasa proses optimasasi. Satu siri ujian yang merangkumi 30 perlaksanaan bagi setiap masalah TSP dinamik dan juga untuk setiap 6riteria masa penukaran telah dijalankan. Objektif kedua penyelidikan ialah menyiasat kesesuaian penggunaan algoritma pencarian tempatan apabila diaplikasikan kepada algoritma terbaik daripada objektif pertama untuk penyelesaian masalah dinamik. Untuk mencapai tujuan ini, tiga algoritma pencarian tempatan iaitu 2-opt, 2.5-opt dan 3-opt telah dipilih untuk diaplikasikan bersama algoritma semut bagi menyelesaikan TSP dinamik. Untuk objektif terakhir, penentuan parameter terbaik bagi algoritma semut bersama dengan algoritma pencarian tempatan dilaksanakan. Analisa hasil kajian menunjukkan bahawa ACS mempunyai prestasi terbaik berbanding lima algoritma yang lain dalam keadaan dinamik. Peningkatan prestasi yang ketara dapat dilihat bagi algoritma semut apabila algoritma pencarian tempatan 3-opt diaplikasikan bersama ACS. Hasil ujian daripada objektif terakhir menunjukkan penentuan parameter terbaik yang berlainan diperlukan untuk menyelesaikan dinamik TSP yang berlainan saiz.*

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