# AN EFFICIENT MULTI JOIN QUERY OPTIMIZATION FOR RELATIONAL DATABASE MANAGEMENT SYSTEM USING SWARM INTELLIGENCE APPROACHES

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PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

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## DEDICATION

To my lord Allah, my Creator teacher and master messenger, Mohamed bin Abdullah (Peace be upon him) my beloved mother, my beloved family, wife and children, all the people in my life who touch my heart, I dedicate this research.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

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PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

## ABSTRACT

Currently, it is fairly obvious that the Multi Join Query Optimization (MJQO) is becoming the centre of attention in the context of Database Management System (DBMS). The functions consist of combination of data from multiple tables, reducing the number of needed queries, optimizing the Query Execution Plan (QEP), and moving processing abounded database servers to enhance both data integrity and performance. MJQO is an optimization task, which serves to locate the optimal QEP of a RDBMS in query processing. A major problem associated with RDBMS is the fact that they are still unable to fully meet the demands of big data. The majority of MJQO techniques encompass solution space at an extremely reduced pace. Many queries attempted to gather information from multiple sites or correlations, while every relation are compelled to answer these query via their limited resources. This lead to the access of data from many locations that are limited in their memory retention capabilities, which inevitably increase the size of the database, the number of the join, and Query Execution Time (QET). In order to eschew trapping and slow coverage difficulties in the quest to discover the optimal QEP and slow query execution time, this work proposes a total of three optimization algorithm that are based on Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), and Two-Phase Artificial Bee Colony (TPAPC) to solve the optimization problem in RDBMS Framework. The TPABC algorithm can be utilized to solve MJQO problems via simulation and increasing exploration and exploitation whilst balancing them for optimal results from giving queries. A directed acyclic graph, based on materialized query graph, aids in the optimization of algorithms and solving MJQO by removing non-promising QEP, which decreases the QEP combination space. Finally, experimental results demonstrate that the performance of TPABC, when compared to PSO, ACO, and native technique in the context of computational time, is very promising, which is indicative of the fact that the TPABC algorithm is capable of solving MJQO problems in shorter amounts of time and at lower costs compared to other approaches.

# ABSTRAK

Sehingga kini, jelas bahawa Pengoptimuman Pertanyaan Gabungan Berganda (MJQO) telah mendapat banyak perhatian dalam bidang *Sistem Pengurusan Pangkalan Data* (DBMS). Fungsinya terdiri daripada gabungan data daripada jadual berganda, pengurangan bilangan pertanyaan yang diperlukan, mengoptimumkan Rancangan Pelaksanaan Pertanyaan (QEP) dan pemindahan pemprosesan pangkalan data pelayan yang banyak untuk meningkatkan integriti dan prestasi data. MJQO adalah salah satu tugas pengoptimuman, ia menggambarkan pencarian QEP yang optimum bagi DBMS dalam pemprosesan pertanyaan. Walau bagaimanapun, penyelesaian kebanyakan teknik MJQO diperoleh dalam kadar yang sangat perlahan. Oleh itu, untuk mengatasi masalah terperangkap, masalah capaian perlahan dalam pencarian QEP yang optimum dan masa pelaksanaan pertanyaan yang perlahan, kajian ini mencadagkan penambahbaikan tiga algoritma pengoptimuman. MJQO yang ditambahbaik diinspirasikan daripada Pengoptimuman Kawanan Zarah (PSO), Pengoptimuman Koloni Semut (ACO) dan dua fasa perilaku Koloni Lebah Buatan (ABC) telah digunakan untuk menyelesaikan masalah dalam Rangka Kerja RDBMS. Objektif utama kajian ini adalah untuk mengoptimumkan QEP dan mengurangkan Masa Pelaksanaan Pertanyaan (QET) dalam RDBMS dengan menggunakan pendekatan kecerdasan kawanan yang diinspirasikan daripada tiga algoritma pengoptimuman, ABC, PSO dan ACO. Oleh yang demikian, Dua Fasa Algoritma Koloni Lebah Buatan yang ditambahbaik (TPABC) digunakan untuk menyelesaikan masalah MJQO dengan simulasi, peningkatan eksploitasi, mutu pencarian dan memberi keseimbangan bagi mendapatkan hasil yang optimum dengan pertanyaan yang telah ditetapkan. Struktur grafik diwakili oleh graf berkitar terarah berdasarkan kenyataan graf pertanyaan, bagi membantu algoritma pengoptimuman dalam menyelesaikan masalah MJQO, QEP yang tidak sesuai telah dipangkas, dengan itu, ia dapat mengurangkan ruang kombinasi QEP. Akhir sekali, hasil eksperimen menunjukkan bahawa prestasi TPABC berbanding PSO, ACO dan teknik naif dari segi pengiraan masa, sangat memberangsangkan dan ini menunjukkan bahawa algoritma TPABC dapat menyelesaikan masalah MJQO dalam masa yang singkat pada kos yang lebih rendah berbanding teknik lain.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

# TABLE OF CONTENTS



PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

# LIST OF PUBLICATIONS

**Journals:**

(i) **Ahmed Khalaf Zager, Rozaida Ghazali and Mustafa Mat Deris,"** An Efficient Multi Join Query Optimization for DBMS using Swarm Intelligent Approach", Publisher in IEEE DOI: 10.1109/7077312, 8-11 Dec. I: 10.1109 / WICT.2014. 7077312.

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PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

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PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

## LIST OF TABLES



PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

# LIST OF FIGURES



PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

# LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| *MJQO* | - | Multi join query optimization |
| *SJQO* | - | Single Join Query Optimization |
| *RDBMS* | - | Relation database management system |
| *QET* | - | Query execution time |
| *QEP* | - | Query execution plane |
| *ABC* | - | Artificial bee's colony |
| *PSO* | - | Particle swarm optimization |
| *ACO* | - | Ant colony optimization |
| *NT* | - | Native Technique |
| *N (Ri)* | - | Set of neighbors for a relation Ri ∈ R w.r.t. G |
| *N(S)* | - | Set of neighbors for a set of relations S ⊆ R w.r.t. G |
| *Min(S)* | - | Relation with the smallest subscript index In a set of relations S |
| *TPABC* | - | Two-Phase Artificial Bees Colony Algorithm |
| *ACOMJQO* | - | Ant Colony Optimization for MJQO |
| *Ci* | - | Set of connected subsets of R with a cardinality of i |
| $2p_s^k$ | - | Set of k-way partitions of a connected subset S |
| $\boldsymbol{p_s}$ | - | Set of partitions of a connected subset S |
| *P* | - | Set of partitions of all the connected subsets in C |
| $\boldsymbol{T_s}$ | - | Multiset of connected subsets in all partitions in PS |
| *T* | - | Multiset of connected subsets in all partitions in P |

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

| | | |
|---|---|---|
| $I_s$ | - | Set of interesting plans for a connected subset S |
| $CSE\ (QEP')$ | - | Set of CSEs of a plan QET′ w.r.t. Q |
| $Cost\ (QEP')$ | - | Cost of a plan QET′ |
| $JoinExp\ (QEP')$ | - | Join expression associated with a plan QEP |
| $CSE\ (QEP)$ | - | Set of CSEs of Query Execution Plane |
| $R = \{R0, \cdots, Rn-1\}$ | - | Set of relations in Q |
| $G = (V, E)$ | - | Query graph for Q |
| $C = \bigcup_{i=2}^{n} C_i$ | - | Set of connected subsets of R with a cardinality of at least2 |
| $Q = \{Q_i, \cdots, Q_n\}$ | - | Set of relations in Q |
| $U_i = \{U_{i1}, \cdots, U_{i\|u1\|}\}$ | - | Set of all the possible plans for Qi |
| $W_i = \{W_{i1}, \cdots, W_{i\|wi\|}\}$ | - | Set of all the possible plans for Qi |

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

# LIST OF APPENDICES



PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

A database management system (DBMS) is a computer software application that interacts with the user, other applications, and the database itself to capture and analyze data. A general-purpose DBMS is designed to allow the definition, creation, querying, update, and the administration of databases. Meanwhile, an RDBMS is a DBMS based on the relational aspect. As of 2015, many frequently used databases are based on the relational database model.

Multi join query optimization (MJQO) for DBMS is perhaps the most important application for searching and retrieving information in shorter amounts of time. The rapid growth in the amount of data available in the world has compelled DBMS to manage its data efficiently. This plays a big role in storage management and maintenance of the data (Wang & Strong, 1996).

Another major player in data management is information retrieval. This is the process of accessing data from relational databases, which is subsequently used to make queries into databases. On the other hand, Structured Query Language (SQL) is a programming language designed for organizing, manipulating, and retrieving data to/from RDBMS (Srivastava & Han, 2012).

A query in RDBMS can be executed via multiple approaches, where each query contains SQL clauses and filters due to a large number of alternative Query Execution Plan (QEP) being possible, making it the main difficult task when selecting optimal QEPs.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

A QEP is represented as a query tree that includes information about the access method available for each relation, as all the algorithms are used in computing the relational operations in the tree. The important step is to generate codes for the selected QEP, which will then be executed in either compiled or interpreted mode to produce the query results (Singh, 2006).

In the case where the query is inserted, a query optimizer provides a large number of execution strategies that are required to analyze the data for execution by checking its validity. Hence, a large number of alternative execution plans are possible, and after a special purpose, it is not possible to analyze every possible query execution plan.

The inability to work with a large amount of data is a problem, and the major concern pertaining to this flaw is the inability to select an optimal QEP for execution. The MJQO problem appears when the number of joins in the query tree increases, which subsequently increases the number of QEP. The traditional approach is very costly and time consuming.

The problem of optimal join order in query optimization is NP-hard (Leo & Cesar, 2008). To reduce its complexity, it should be followed up with a well-accepted heuristic in RDBMS (Moerkotte & Neumann, 2006). On the other hand, (David & Frank, 2007) accounted for all bushy plans, but excluded a cross product mathematically from the enumeration space. Thus, in many case, the query optimizer ends up having to optimize for a plan that has nearly optimized.

An optimal QEP has always depended on the number of tuples used in a query. It means that the query optimizer primarily relies on statistical information to make tuple assessment, and it always depends on the accuracy of tuple assessment. Increasing the qualities of the selection process of an optimal QEP relies on additional CPU cost and increased memory consumption. Cost estimation models are mathematical algorithms or parametric equations used to estimate the costs of a QEP in terms of time or memory consumption (Dong & Shivnath, 2011).

RDBMS is the most well-known database being used nowadays, which is based on the relational database model (Leo & Cesar, 2008). Query language is an effective tool, which provides an interface to a user to store and access data. In the past few decades, SQL has emerged as a standard query language (Vidya Banu & Nagaveni, 2012); (Rashid & Ali, 2010); (Chaudhuri & Krishnamurthy, 1995).

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

Two components that are evident for query evaluation are the query optimizer and the query execution engine (Chaudhuri & Kr).An optimal solution should be able to evaluate the connected subset enumerate (CSE) once and reuse their results for subsequent queries to improve overall query performance. Complex multi-join queries usually takes longer to evaluate due to the inherent complexity of the queries. There could be considerable performance saving by sharing the computation of CSE among the queries.

In an RDBMS context, it was shown that substantial performance saving can be obtained by using MJQO techniques. In addition to MJQO techniques in the RDBMS context, there are also some preliminary studies (Chaudhuri & Ger, 2006); (Tomasiz *et al.*, 2010); (Lim & Herodotou, 2012) on the MJQO techniques in the DBMS context proposed by Google (Dean & Ghemawat, 2004), which have recently emerged as a new paradigm for large-scale data analysis and widely embraced by Amazon, Google, Facebook, Yahoo!, and many other companies.

There are two key reasons for this; first, the framework can be scaled to thousands of commodity machines in a fault-tolerant manner, and is thus able to use more machines to support parallel computing. Second, the framework has a simple yet expressive programming model through which users can parallelize their respective programs without being concerned about issues such as fault tolerance and execution strategy (Deng & Chain, 2014).

While all MJQO techniques (Prasad &, Deshpande, 2011), (Yihong et al., 1998), (Nilesh *et al.*, 2003) have been extensively studied in the RDBMS context, most mainly focus on optimizing a handful of SQL join queries. MJQO problem in the RDBMS context differed from these works, since the focus on optimizing a large collection (hundreds or thousands) of cross product queries produced by the applications of enumerative set-based queries.

In a traditional database, the total numbers of relations in multi-join queries are usually less than 10, which can be effectively handled by dynamic programming approaches. The complexity of this problem increases due to generation of complex multi-join queries in certain modern applications, such as knowledge-based systems, decision support systems, expert systems, Online Analytical Processing (OLAP), and data mining.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

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PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

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PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

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