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Performance prediction and adaptation for database management system workload using Case-Based Reasoning approach☆

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ABSTRACT

Workload management in a Database Management System (DBMS) has become difficult and challenging because of workload complexity and heterogeneity. During and after execution of the workload, it is hard to control and handle the workload. Before executing the workload, predicting its performance can help us in workload management. By knowing the type of workload in advance, we can predict its performance in an adaptive way that will enable us to monitor and control the workload, which ultimately leads to performance tuning of the DBMS. This study proposes a predictive and adaptive framework named as the Autonomic Workload Performance Prediction (AWPP) framework. The proposed AWPP framework predicts and adapts the DBMS workload performance on the basis of information available in advance before executing the workload. The Case-Based Reasoning (CBR) approach is used to solve the workload management problem. The proposed CBR approach is compared with other machine learning techniques. To validate the AWPP framework, a number of benchmark workloads of the Decision Support System (DSS) and the Online Transaction Processing (OLTP) are executed on the MySQL DBMS. For preparation of training and testing data, we executed more than 1000 TPC-H and TPC-C like workloads on a standard data set. The results show that our proposed AWPP framework through CBR modeling performs better in predicting and adapting the DBMS workload. DBMSs algorithms can be optimized for this prediction and workload can be controlled and managed in a better way. In the end, the results are validated by performing post-hoc tests.

1. Introduction

Workload management in the Database Management System (DBMS) plays an important role in its performance tuning. Database workload consists of a batch of queries or requests that are executed in a DBMS. The volume of data is increasing day by day which in turn increases the complexity of data management and decreases the performance of a database. For humans, it has become difficult or even impossible to manage the large-scale data due to its complexity and heterogeneity. Due to this, it gained the attention of DBMS researchers and vendors to build such types of DBMSs that have the capability of managing activities proactively. In DBMSs, as it is difficult to monitor and control the workload before execution, therefore, its performance could not be determined beforehand. If we know the performance of a workload in advance, we can control its management. Similarly, other DBMS issues such as system sizing and capacity planning cannot be handled without knowing the information about a workload before its execution. In workload management, many questions arise regarding workloads, such as, when to execute a workload or stop a problematic workload and what will be its performance? and other questions related to system sizing and capacity planning. The Autonomic Computing (AC) technology can be used

Abbreviations: DBMS, Database Management System; AWPP, Autonomic Workload Performance Prediction; OLTP, Online Transaction Processing; KCCA, Kernel Canonical Correlation Analysis; CBR, Case-Based Reasoning; DBA, Database Administrator; AC, Autonomic Computing; KNN, K-nearest neighbor; SVM, Support Vector Machine; TPC, Transaction Processing Council; QEP, Query Execution Plan; WFV, Workload Features Vector; PMV, Performance Metrics Vector; Dbt2, Database test 2; ET, Execution Time; WL Size, Workload Size; APV, Adjusted p-value.

☆ The TPC benchmark setups have not been audited as per TPC specifications, TPC-H and TPC-C mean TPC-H like and TPC-C like queries as our representative workloads.

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in self-management of a DBMS workload that can enable a system to handle the workload with less or no human involvement. Many algorithms, frameworks, and tools have been developed for managing a database workload autonomically [1,2]. The autonomic workload management has incorporated a few autonomic characteristics which include self-inspection, self-optimization, self-adaptation, self-configuration, and self-prediction [3–5]. The prediction of a few database performance metrics has been performed in literature; however, many performance metrics are yet to be investigated which can be helpful in scheduling, adaptation, optimization, and resource allocation in DBMSs. As a workload may change anytime, due to its evolving behavior, so the workload adaptation is becoming a need for database systems. Many researchers have developed adaptation frameworks and models by using traditional approaches to solve workload adaptation issues. Currently, several research works are being carried out in designing applications and systems having self-* properties of AC [6,16–18,30,52].

The study provides a solution for predicting the performance and adapting the changing behavior of the workload. An Autonomic Workload Performance Prediction (AWPP) framework is developed for predicting the performance metrics which is helpful in performance tuning of DBMS. For workload performance prediction, the Kernel Canonical Correlation Analysis (KCCA) algorithm computes the distance between new query projection and existing query projection using K Nearest Neighbor (KNN). However, it is not adaptive as it computes the distance for each new query [19]. In this study, for workload performance prediction, Case-Based Reasoning (CBR) approach is used that works through reasoning based on available solution-cases stored in the repository and provides the required solution. The CBR has four phases that are Retrieve, Reuse, Revise, and Retain [36]. It works autonomically without human involvement, however, initial training is required by the Database Administrator (DBA). For workload performance prediction and adaptation, the cases are retrieved and retained in the repository making it predictive and adaptive. The performance of the proposed CBR approach is compared with other machine learning techniques. The AC properties such as self-inspection, self-prediction, and self-adaptation are incorporated in AWPP framework. Upon execution firstly, the workload self-inspected to extract its metrics. Performance metrics are predicted through self-prediction and self-adaptation is performed to adapt according to behavioral changes in the workload. The training and testing data is created by executing several workloads which enabled in predicting the workload performance.

The objectives of the study are as follows. The first objective is to propose a workload performance prediction framework. The second objective is to predict the performance metrics of the workload before executing it based on workload metrics. The third objective is to adapt the changes to the changing behavior of workload. The contributions of the study are described here. It provides CBR-based AWPP framework that produced effective and accurate workload performance prediction and has the ability of workload adaptation. MySQL status variables are studied and existing features from different studies are analyzed. Additional metrics are identified that has an impact on workload performance predictions. The proposed AWPP is compared with well-known machine learning techniques and is evaluated through evaluation measures that include effectiveness, accuracy, adaptiveness, and significance. Post-hoc test is performed to validate the results. The rest of the paper is organized as follows. Related work is presented in Section 2. The proposed AWPP framework is described in Section 3. The evaluation of the proposed AWPP framework using CBR and machine learning techniques is provided in Section 4. Results and discussions are presented in Section 5. The conclusion of the paper and future work is presented in Section 6.

2. Related work

Autonomic Computing (AC), is an important technology has been used in many application areas, including web services [21,22] and databases [24–26,28,29]. AC performs the tasks in a system autonomically without or less human intervention, i.e. self-management [5]. The concept of self-management is taken from the nervous system of human [3]. AC helps in predicting the behavior of a system which is also being used for workload performance prediction in DBMSs. Prediction is performed for forecasting the time ranges [41], throughput and response time [42]. Machine learning has been used for predicting the performance metrics of a workload [19]. The performance metrics that have been predicted include message bytes, message count, records used, records accessed, disk I/O, and elapsed time. KCCA algorithm is used for finding a correlation between query and performance metrics. The projection for new query is performed using KNN for finding the nearest neighbor that predict the performance metrics. Research is also carried out for modeling and predicting the workload performance [20]. Adaptiveness is achieved by researchers using different techniques and approaches such as fuzzy logic [27] that uses Fuzzy Inference System (FIS) to predict buffer-hit-ratio, database size, and the number of users. The studies Rosas et al. [7] provides an adaptive methodology for performance improvement in large data using data partition, processing nodes and adapting size.

A learning-based framework WiSeDB [9] has been proposed for workload management. It works on workload characteristics and performance goals. For resource provisioning and scheduling, decision tree approach is used to adapt offline model for retraining the performance goals with low training overheads. The adaptation is fast for performance assessment and cost trade-offs. The study Singhal and Nambiar [15] provided a modular approach for estimation of the execution time of an SQL query for high information volume. The studies Wu et al. [13,14] predicted SQL query execution plan and proposed prediction of accurate estimation of disk visits and CPU time for large data size. For CPU performance prediction, different models have been proposed such as query execution prediction model [8], performance model [9] and framework COMPASS [10]. PEMOGEN [11] predicts query response time that works on the neural system. The MAG framework is presented in [23] to control, monitor, predict and analyze the configuration parameters that works for performance problems of the database. Performance and resource analysis has been performed using a framework that predicts resource consumption, bottleneck, and throughput [40]. The work Hasan [12] provides the performance prediction of SPARQL query through machine learning techniques. Our work is different from the existing studies as it provides a framework that takes workload as input and predicts the performance of that workload and also handles the evolutionary behavior of the workload through adaptation without human intervention.

3. Proposed AWPP framework

In this section, we present the proposed Autonomic Workload Performance Prediction (AWPP) framework and describe its all components, input/output and autonomic functionality using CBR approach. The AWPP consists of three components as shown in Fig. 1. These components are *Features Extraction, Workload Performance Prediction*, and *Workload Adaptation. Workload feature extraction* and *Performance metrics extraction* are two sub-components of *Features Extraction* component. *Workload Performance Prediction* forecasts the performance of the workload using machine learning techniques. *Workload Adaptation* retains the workload on the change in behavior.