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Data Mining Approach for Commercial Data Classification and Migration in Hybrid Storage Systems

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Abstract**—**Parallel hybrid storage systems consist of a hierarchy of different storage devices that vary in terms of data reading speed performance. As we ascend in the hierarchy, data reading speed becomes faster. Thus, migrating the application' important data that will be accessed in the near future to the uppermost level will reduce the application I/O waiting time; hence, reducing its execution elapsed time. In this research, we implement trace-driven two-levels parallel hybrid storage system prototype that consists of HDDs and SSDs. The prototype uses data mining techniques to classify application' data in order to determine its near future data accesses in parallel with the its on-demand request. The important data (i.e. the data that the application will access in the near future) are continuously migrated to the uppermost level of the hierarchy. Our simulation results show that our data migration approach integrated with data mining techniques reduces the application execution elapsed time when using variety of traces in at least to 22%.

Keywords**—**Data mining, hybrid storage system, recurrent neural network, support vector machine.

I. Introduction

PARALLEL hybrid storage systems consist of a hierarchy of storage devices that differ in terms of data reading speed performance where data reading speed becomes faster as we ascend in the hierarchy. Applications continuously issue on-demand data reading requests from the storage system. Therefore, it is better to find the requested data in the uppermost level to reduce the retrieving time for requested data.

Data mining techniques are able to classify the data of a wide variety of data sets based on their importance. Important data are those that will be accessed in the near future and those most frequently used. This process allows us to migrate the application' future data requests in the hybrid storage system levels based on the importance [1]. This will reduce the application execution elapsed time. I/O intensive application and their users vary in their access patterns. This makes the process of data classification depends on the application type. Application types include, but not limited to, database applications, image processing applications, marketing, finance, voice, and text recognition ... etc. Different classification or data mining approach may provide better accuracy for a type of an application than the others [2].

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In this study, we used a prototype of a two levels parallel hybrid storage system that consists of an array of Solid State Drives (SSDs) in the uppermost level and Hard Disk Drives (HDDs) in the lower level. While the application issues on-demand I/O reading requests, data mining techniques performs the highest possible accurate data classification for specific application type to predict its near future accesses. Predicted near future accesses; which we call: important data; will be automatically migrated to the uppermost level of the hierarchy (i.e. SSD level). As mentioned, three data mining techniques will be used, which are: 1) Echo State Network (ESN) [4], 2) Simple Cycle Reservoir (SCR) which is extended in Cycle Reservoir with regular jumps (CRJ) [5], and 3) Support Vector Regression (SVR) [6]. This data migration makes the uppermost levels to accommodate important data. Hence; reaching the ultimate goal of the proposed approach which is reducing the application' execution time by reducing the storage' I/O stalls caused by big difference between HDDs and SSDs disk read latency.

A. Contribution

In this research, we focus on data migration in a parallel hybrid storage system using a data mining approach for commercial marketing websites. Our study objectives are summarized in the following key points:

1) Modeling a data mining algorithm that performs the highest possible accurate data classification for specific application type in parallel with the application on-demand request.
2) Implementing our approach in a parallel hybrid storage system in order to migrate the data based on their importance; where uppermost levels accommodate important data.
3) We aim to build a prototype that evaluates our proposed approach in a parallel hybrid storage system. Accuracy in data classification is our major performance metric.

II. Background

Hybrid storage system consists of hierarchy of different storage devices that vary in their speed performance, energy consumption, and size capacity. Hybrid storage system provides efficient solution for accommodating large amount of data, which low cost, without affecting the I/O response time. In particular, speed performance and energy consumption are increased as we go downward in the hierarchy. On the other hand, the size is increased as go upward.

Modern Hybrid storage system is a typical storage device that includes main memory, solid-state disk (SSD), hard disk drive (HDD), and magnetic tape. The SSD resides at the top of storage hierarchy. SSD shows the best performance in terms of speed and energy consumption. In this multi-level storage system, when the application issues on-demand data requests, the system checks if the data is residing in their uppermost level storage device (SSD). If not, the system checks the next storage level (HDD) and so on.

Echo State Network (ESN) supplies supervised learning standard and architecture for recurrent neural network (RNN). ESN is backpropagation decorrelation learning rule for RNN that subsumed under a Reservoir computing name. CRJ is also used to classify the preprocessed data in the proposed approach. Standard ESN has serious of a problem affects its acceptability. Thus, the CRJ was proposed by [3] to solve these problems.

Support Vector Machine (SVM) is based on decision planes that define the decision boundaries between different data categories. A decision plan differentiates between a group of objects with different class memberships [6].

III. System Model

The propose of this research is to build an approach for a fast-response single or multi user's application that runs on the top of a two levels hybrid storage system (SSD and HDD). To facilitate a fast response, a data-mining module is used to keep building a history and keep issuing data migration decisions based on data importance (important data: is that that will be accessed in the near future).

Data mining techniques are able to classify the data based on their importance. In this study, we propose a data mining approach that performs the highest possible accurate data classification for a commercial marketing website's applications in parallel with its on-demand request. The proposed approach can also be applied on other applications that include, but not limited to, database applications, image processing applications, marketing, finance, voice and text recognition…. etc.

Our system consists an application that accesses a multi-level hybrid storage system which is maintained by data mining techniques. The application issues on-demand data requests and runs on the top of a two levels hybrid storage system (SSD and HDD). The uppermost levels (SSD) will be used to accommodate data that will be accessed in the near future. This important data will be continuously migrated to the SSD level to reduce the application data retrieval time. (See Fig. 1 that illustrates the architecture of the proposed approach).

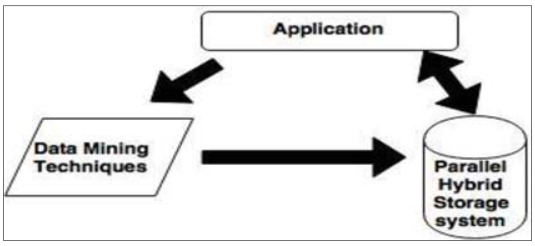

Fig. 1 System Architecture

A. Data Mining Techniques

The purpose of the data-mining step is to classify the normalized data based on their importance. Data that will be accessed in the near future are considered important data. In general, the classifier builds a model based on the data used in the training phase. The model is used to predict the classes of the unknown class data in the testing set. This process is illustrated in Fig. 2. Several methods for used data classification are discussed in the following subsections.

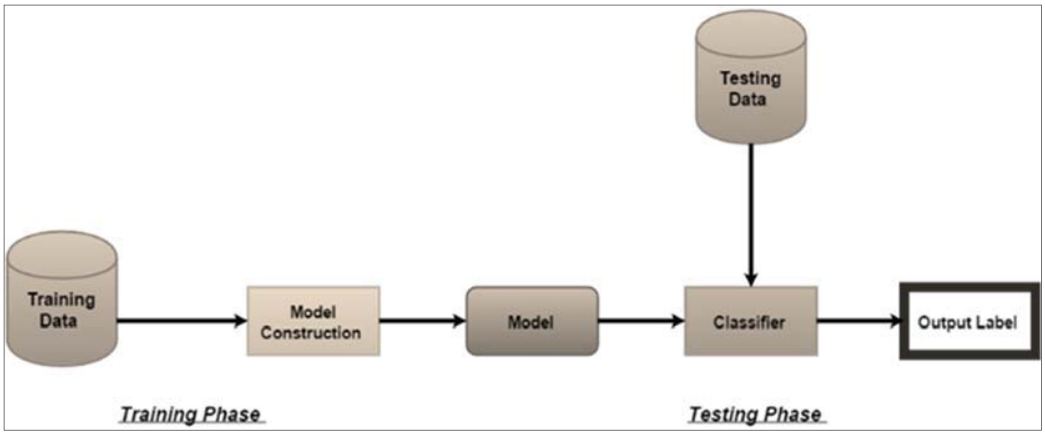

Fig. 2 Data classification process

The processed data are inserted into the data mining techniques that is related to each other. In the same time, the application continuously issues on-demand data requests; those requests have repeated patterns. Thus, the purpose of the utilized data mining techniques is to train a model that is able to figure out these repeated relations. Subsequently, for a new request, the model will be able to predict the most probable

future request(s). So, data mining techniques are used to find out a model for the mentioned purpose.

A. Data Prefetching

The last step is to inject the data, which has been processed previously, into the Parallel Hybrid Storage System [7]. The storage system consists of an array of two levels of storage devices (SSD in the top and HDD in the bottom. See: Fig. 3).

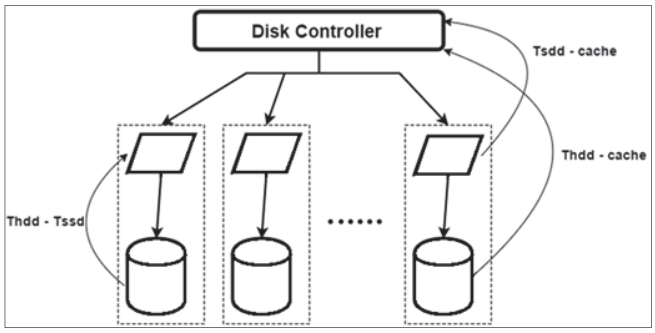

Fig. 3 Parallel Hybrid Storage System design

When the application issues on-demand data request, the system first looks for the data in SDD level. If the data is not found, the system looks for the data in the HDD level. More hits in SSD level will decrease data retrieval time and hence; decrease the application's execution elapsed time. In our system, all the data are initially stored in the HDD level due to its large capacity. Also, this represents the worst case scenario. As the application runs, the data will be migrated from the HDD level to the SSD one as the classification process is executed. However, instead of completely migrated the data, copies of the data are fetched from HDD to SSD to save the storage system's bandwidth. If a particular data is initially allocated in the SSD level, then no data migration will take place for that data.

Our system assumes that the maximum bandwidth (MaxBW) for the parallel hybrid storage system is equal to the maximum number of concurrent reading requests that may take place in the storage system without causing any congestion [7]-[10]. Because each disk can handle at least one data request without congestion, the MaxBW is set to the size of the parallel hybrid storage system array. Our system assumes that there is no caching. Also, the application can only issues one on-demand data request at the time and the rest of the MaxBW is used for data migration.

IV. Experimental Result

In the proposed approach, the maximum bandwidth is set to be five, one for the application on-demand request and the rest for prefetching process. In the experiments, it was found that it is sufficient to set the maximum bandwidth to two because the data mining techniques that are used required one-step for prefetching. However, the value of five is required if more than a single prefetching is implemented.

Two System call traces from SANIA Laser Repository, called Machine01 [11] and Machine06 [12] were used for the experimental results. Machine01 and Machine06 differ from each other in the acquired time series; Machine06 was acquired from computers running for longer time compares to Machine01. The two traces have a repeated pattern property which serves our model goal.

The results are collected for testing data of different sizes, which represent the testing set that have been used to testing the models in the experiments of the data mining techniques.

To evaluate our system model and calculate the elapsed time based on some parameters, which are:

- **Thdd-ssd:** the time to fetch data from HDD to SSD.
- **Thdd-cache:** the time to fetch data from HDD to Cache.
- **Tssd-cache:** the time to fetch data from SSD to Cache.

The results were evaluated using elapsed time as given in (1).

$$ElapsedTime = ((Acc.\times TestSize)\times Tssd\cdot cache + ((FalseNegative\times TestSize)\times Thdd\cdot cache) \quad (1)$$

where accuracy is the percentage of the truly prefetched data, TestSize is the number of dataset blocks that enter the data mining Techniques and the FalseNegative is the data that was not predicted.

As for the parameter settings, specifically for the parameters Thdd-cache, Thdd-ssd, Thdd-ssd, and Tssd-cache, the values are obtained from [7] as indicated in Table I.

TABLE I
Value of HSS Parameter

Datasets	Machine01, Machine06
Maximum Bandwidth	5
Block Size	10MB
Predict Depth	4
Time from HDD to SSD	0.1225
Time from HDD to Cache	0.12
Time from SSD to Cache	0.052

TABLE II
Experimental Result

Traces	Machine01	Machine6
ESN		
Random Elapsed Time	9.1832	39.5733
Elapsed Time with Our System	7.1596	25.37
Enhancement	22.0359 %	35.8911 %
Model Accuracy	41.9920 %	67.1845 %
CRJ		
Random Elapsed Time	9.1832	39.5733
Elapsed Time with Our System	7.0465	25.773
Enhancement	23.2675 %	34.8728 %
Model Accuracy	43.3625 %	65.4455 %
SVR		
Random Elapsed Time	9.1832	29.8533
Elapsed Time with Our System	7.1407	21.4638
Enhancement	22.2417 %	28.1024 %
Model Accuracy	41.5821 %	54.6328 %

Table II shows the experimental result after applying our method with the data mining techniques and it shows the comparison and enhancement with and without our method.

V. Conclusion and Future Work

A Parallel Hybrid Storage System (PHSS) with embedded data mining techniques was developed and tested. The data are migrated from HDD to SSD based on its expected demands using the embedded data mining technique. The utilized CRJ and ESN outperforms the traditional SVR model in this context.

Based on the conducted theoretical and experimental study, it was clear that ESN gives different accuracy results with different data due to its random weight generation. While, CRJ always gives the same accuracy. Subsequently, we can argue that CRJ out performs ESN.

A simulation of the parallel hybrid storage system over SANIA dataset leads to the following conclusions:

- Using a training model in machine01, CRJ is the best model ith minimum elapsed time.
- Using a training model in machine06, ESN is the best model ith minimum elapsed time.

Our future work will focus on applying the proposed system in three layers of a hybrid storage system (SSD, HDD, and tape) rather than just two layers, to make the system fetch the most important data to SSD, the less important data to HDD, and the remainder non-value data will lodge in the tape.

Also, it is worthy to apply the proposed system in different application types, such as: university website, image processing application, finance software, and many others.

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