Exploring the self-similar characteristics of I/O workload for optimization of computational throughput in High energy physics data analysis

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Introduction

A job of High Energy Physics is usually a reconstruction or analysis program running on millions of events that generates lot of temporary data and final output results that needs to be written to persistent storage. For that there is need to design a computing system that can efficiently handle the data throughput for such jobs. Performance of a computing system depends on the nature of workload that it is going to encounters. The nature can be determined by analyzing the existing workload trace for eg. I/O workload trace.

I/O traces contain valuable information about the workloads encountered in production environments. By studying a trace one can optimize a system for the specifics workload. Traces are also useful for the proper performance evaluation of the existing systems. But synthetic benchmarks are easy to use and can scale the load efficiently. In this work we are trying to explore the available I/O workload traces to find whether they follow any specific pattern. Based on this, new models can be developed that may synthesize the real workload and hence can be used to benchmark the existing system and in designing of new computing system

Need of workload analysis

One of the biggest difficulties faced by storage researchers is how to benchmark the system to compare different designs and to test the efficacy of a new design. A solution to this is to analyze the existing workload and get the important statistical parameter. These parameters can be used to design a workload model and use that model to develop a synthetic workload generator to benchmark and compare different designs.

I/O workload Trace data

The I/O trace data used in this work is taken from Umass Trace Repository [1]. The trace file is composed of variable length ACSII records. This file is filtered so that we get only lower level block I/O information with timestamps which we have used in this work.

Description of self-similarity and its presence in I/O workload

A self-similar[2] process is a process that looks similar across all time-scales. Fig 2 shows segment of data of Fig 1 at resolution of 0.2 secs. From these plots it is very clear that the disc access process is having a bursty behaviour that appears similar and is independent of time scale. This fact provides strong evidence of the self-similar nature of the I/O workload.

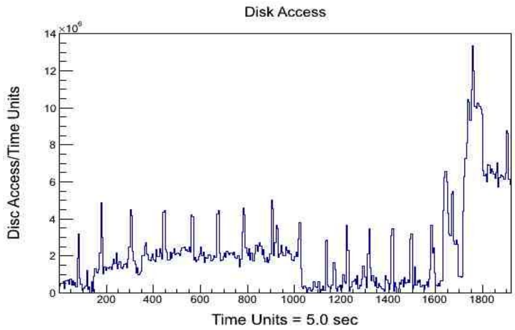

Fig 1: Disc access pattern with resolution of 5 secs

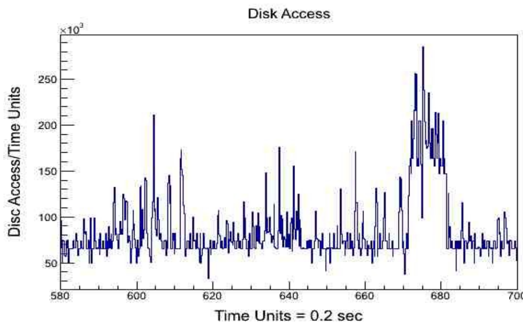

Fig 2: Disk access pattern for a segment of data at a resolution of 0.2 secs

Estimating Hurst parameter to detect and estimate self-similarity

Estimating the Hurst exponent[3] for a data set provides a measure of, whether the data is a pure white noise random process or has underlying trends. Or one can say that a random process with an underlying trend has some degree of autocorrelation. When the autocorrelation has a very long (or mathematically infinite) decay this kind of Gaussian process is sometimes referred to as a *long memory process.*

Statistically it is seen that if the Hurst exponent(H) is $0.5 < H < 1.0$, the random process will be a long memory process and shows self similar characteristics. Data sets like this are sometimes referred to as fractional Brownian motion (abbreviated fBm)

Here we are calculating hurst exponent using following different methods[4] : (i) Rescaled range (R/S) analysis (ii) analysis of the variances of the processes , and (iii) periodogram-based analysis in the frequency domain.

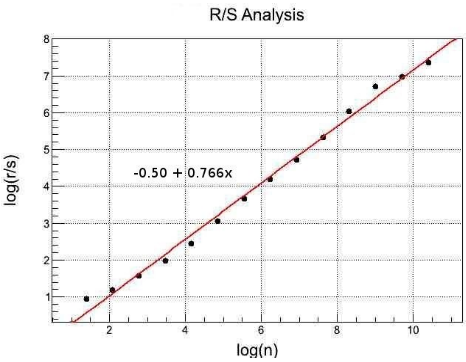

Fig 3: R/S Analysis plot

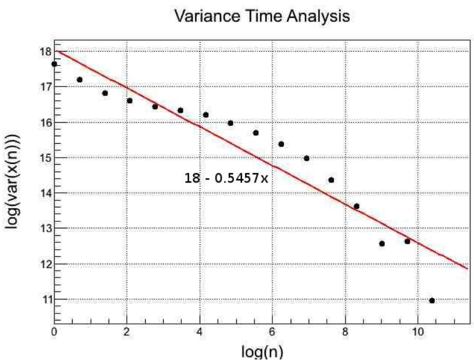

Fig 4: Variance time Analysis plot

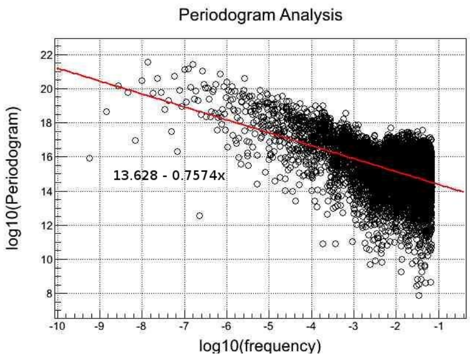

Fig 5: Periodogram Analysis plot

Fig. 3, 4, and 5 above shows plot of various methods used for calculation of Hurst exponent and the parameter's value is summarized in Table 1 below.

Analysis Method	Hurst Exponent
Rescaled Range (R/S)	0.766
Variance Time Plot	0.727
Periodogram	0.878

Table 1: Hurst Exponent calculated from different methods

All the values from the above table clearly mentions the existence of self-similarity in I/O workload.

Conclusion and future work

We have presented an analysis of I/O workload trace data. The results show strong evidence of self-similar nature of disc access process. In future work we will try to model the self-similar nature of disc access using statistical distribution like Pareto distribution and will compare the simulated results with real I/O workload trace.

References

[1] http://http://traces.cs.umass.edu/
[2] http://en.wikipedia.org/wiki/Self-Similarity
[3] http://www.bearcave.com/misl/misl_tech/wavelets/hurst/
[4] Tatsuya Hagiwara et. al. IEICE TRANS. INF. & SYST., VOL. E84-D,NO.5 May 2001