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The Performance Analysis for Embedded Systems using statistics methods

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Abstract

Performance comparison for the computer system under different hardware platform & system structure is of vital importance in the study of the performance evaluation. The Performance Analysis for Embedded Systems by using statistics methods based on the randomized complete block designs was proposed. Using the randomized block design, the differences between conditions can be separated from the difference in the processing, and be separated from the experimental bias. A case study of automatic gate machines used in the automatic fare collection system of Shanghai Metro is presented. The obtained assessment results show that our approach is helpful and effective.

Keywords: *randomized complete block design, embedded system, performance analysis, performance benchmarks, hypothesis testing*

1. Introduction

Several common performance evaluation technologies have been proposed for general computers [2] [3], such as analysis [4], simulation [5] [6], measurement based method, benchmarking and so on. These methods have different characteristics, and are suitable for different stages in the life cycles of a target system. Among these approaches, benchmarking has been achieving a great many considerations in recent years, because it has direct, simple and low cost properties.

Performance analysis based on the test is one of the commonly used methods for performance assessment. Any set of test data can be viewed as a model or permutation under all conditions studied. Any measure with a certain degree of random error, so the results must be integrated a lot of test data in order to make the conclusion with sufficient accuracy. One of the important roles of the statistics is to provide a reasonable basis to determine the number of repetitions of the test. And in performance comparison, the existing methods is generally first to make sure a basis of comparison, guidelines, and get the index value of the system in order to determine the merits and demerits of their performance by testing or with other methods. In the case of relatively simple or quite different indicator values, this method is simple and practical. But when the process is complex or the index value is closer, this way often comes to the wrong or inappropriate conclusions. The purpose of this paper is precisely to solve the problems encountered by comparison in this case, analyzing the test data with the view of statistical point to make the results more objective. In addition, when studying the various factors that affect performance, the method that fixing other factors to make the study to make certain change is frequently used. But due to random bias and measurement error are intertwined, data processing becomes cumbersome.

Repeat the test can drawn random error, but conducting a comprehensive test will undoubtedly increase the testing workload. Through the use of randomized complete block design, under the same conditions each time only a group of testing, and that the corresponding conditions between groups is allowed different, can make the testing workload is greatly reduced. Therefore, this paper proposes an analysis and comparison method of embedded systems performance based on randomized complete block design. The method can distinguish the impact of the test error on the gap of actual performance and is especially suitable for the more than two kinds of different product comparison. By using complete block design can effectively reduce the repetitions of the test, making testing more efficient. Finally, we apply

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them to the embedded system performance tests of the Shanghai urban rail transit AFC system terminal equipment (automatic ticket checking machine), and obtain rather satisfactory results.

2. The Analysis and Comparison Based on Randomized Complete Block Design Performance

2.1. General Framework

This paper proposes a set of design thinking to guide test design method, the test design process as follows:

Identification and formulation of the problem: Clearing the test purpose need to attract the participation of all related personnel which includes: designers, testers, users, operators, etc. Usually, they would have a lot of ideas, but often easily ignored.

The choice of factors and levels: Select the prepared change factors in the test, the extent of these changes, as well as provisions level of these factors at the time of testing. And how to control these factors in the expected range must be considered, as well as how to measure these values. Carefully study and analyze the important factor all possible, especially in the early stages of testing.

The choice of response variable: when choosing the response variable, we should ensure that a variable would really provide useful information for the research process. Generally the average, standard deviation or both of the measurement characteristics can be taken as a response variable.

The division of the block: depends on the level of factors and the response variable choices.

Implementation of the test: When testing, monitor the testing process to ensure that every process in accordance with the test plan. Making plan in the first is the key of success. Keep in mind the purpose of testing in the testing process, as in some of the testing process, in the beginning we have know that the level of some of these factors will make the response arrive at different values. When comparing the two systems A and B that A is the standard but the cost of B is lower or B has other advantages, the tester will be interested to find out whether there is any difference between their performances.

Data Analysis: Analysis of the data by using statistical methods can make conclusions and results more objective. Statistical methods cannot prove that a factor (or several factors) has a special effect. They only provide guidelines to the reliability and validity of the result of the test.

2.2. Statistical Analysis

Generally speaking, if you want to compare a processing and have b blocks, within each block, each processing will have a test value, to take the statistical model of this design is:

$$y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij} \begin{cases} i = 1, 2, \ldots, a \\ j = 1, 2, \ldots, b \end{cases} \tag{1}$$

μ is the population mean, τ_i is the effect if i kinds of processing, β_j is the effect of the j block, ε_{ij} is the usual random error. The processing and block are the fixed factors, the effect of them is defined as the deviation of the total mean, and our interests liein testing whether the processing mean is equal. So, it can assume

$H_0 : \mu_1 = \mu_2 = \mu_3 = \cdots = \mu_a$

$H_1 : \tau_i \neq 0$, for at least one i

By the normality hypothesis for the bias, we can prove that $\frac{SS_{\text{processing}}}{\sigma^2}, \frac{SS_{block}}{\sigma^2}, \frac{SS_E}{\sigma_2}$ are independent distribution of chi-square random variables from CACHRAN theorem [7].

It can be proved that the expectation of the mean square is as the following:

$$E(MS_{\text{processing}}) = \sigma^2 + \frac{b\sum_{i=1}^{a}\tau_i^2}{a-1} \tag{2}$$

$$E(MS_{block}) = \sigma^2 + \frac{a\sum_{i=1}^{b}\beta_i^2}{b-1} \quad (3)$$

$$E(MS_E) = \sigma^2 \quad (4)$$

Where σ^2 is the population variance.

Therefore, the equation $F_0 = \frac{MS_{\text{processing}}}{MS_E}$ can be used to test the processing mean.

When the zero hypothesis is true, its distribution is $F_{a-1,(a-1)(b-1)}$, reject region is on the F distribution's tail when $F_0 > F_{\alpha,a-1,(a-1)(b-1)}$ (α is called the test significance level), reject H_0。

Then we can get the randomized complete blocks design, which is shown in the following Table 1

Table 1. The variance analysis table of the randomized complete blocks design

Variation source	Square Sum	Mean Square	F0
processing(operating system type)	1245.46	622.73	
block(index type)	824348	412.24	38.04
error	98.2	16.37	
sum	2168.14		

2.3. Relative Efficiency

In the above, we illustrate the error reduction nature of the randomized complete block design. We note that among the not computing process total sum of squares (see table 2) the error form the difference among blocks may be accounted for the total proportion of more, and so if we do not use randomized complete block design test, the values of MSE may be too big that don't have sensibility as randomized complete block design.

Estimated randomized complete block design is helpful to the relative efficiency of general testing. A way to define this relative efficiency is Eq.5:

$$R = \frac{(df_b+1)(df_r+3)}{(df_b+3)(df_r+1)} \cdot \frac{\sigma_r^2}{\sigma_b^2} \quad (5)$$

Where σ_r^2 and σ_b^2 represent the test errors of completely random design and general testing respectively, df_r and df_b represent the degrees of freedom of the corresponding error. This statistics can be viewed as the increase multiples of general testing of the same sensitivity randomized complete block design in the number of repetitions.

In order to calculate the relative efficiency, there should be the estimates values of σ_r^2 and σ_b^2. Randomized complete block designed MS_E is the unbiased estimator of σ_b^2, and then can prove Eq. 6

$$\tilde{\sigma}_b^2 = \frac{(b-1)MS_{block} + b(a-1)MS_E}{ab-1} \quad (6)$$

is the unbiased estimator of the error variance of σ_r^2.

3. The Test of Automatic Ticket Checking Machine's Performance

3.1. The Construction and Performance Index of the Automatic Ticket Checking Machine

Urban rail transit's automatic ticket checking machines are installed in the juncture of station pay area and non-pay area, they can accept the dedicated tickets for the rail traffic and the public transport card, and meet the requirements of passengers holding tickets pass quickly.

For the automatic ticket machine system, the performance index whether to meet the business needs is related to its success. Therefore, the performance testing is particularly important for the automatic ticket machine system. The main performance index we are concerned about is the transaction processing time, which includs one-way ticket inbound, transportation card inbound, one-way ticket outbound and transportation card outbound. Taking the transaction processing time of one-way ticket inbound for example to specify the meaning of these index and how to calculate their values.

Table 2. Complete block design (Unit: ms)

processing / time	block			
	one-way ticket inbound	one-way ticket outbound	transportation card inbound	transportation card outbound
ReWorks	52.5	63.4	35.9	48.8
Linux	237	178	239	97
Windows XPE	52	60	36.5	45.1

All the test results can be arranged 3×4 test units randomly according to different operating systems and test index, and record the corresponding test data, and the 12 test units can be divided into four blocks according to the transaction processing time of one-way ticket inbound transportation card, inbound one-way ticket, outbound and transportation card, outbound and the automatic ticket machines of different operating systems processing differently, a complete block design as shown in Table 2, the values in the table are the test average.

Then the analysis of variance as shown in Table 3 can be obtained.

Table 3. The analysis of variance

Sources of variation	Sum of squares	Mean square	F0
Processing (the type of operating system)	1245.46	622.73	
Block (the type of index)	824.48	412.24	38.04
Error	98.2	16.37	
sum	2168.14		

Take α as 0.05, the critical value of

$$F_{\alpha,a-1,(a-1)(b-1)} = F_{0.05,2.6} = 3.74$$

Then we can draw the conclusion: Automatic ticket machines in the operating system have a significant performance difference caused by bias for little possibility because 38.44>3.74.

$$\tilde{\sigma}_r^2 = \frac{(b-1)MS_{block} + b(a-1)MS_E}{ab-1} = \frac{3\times412.24+4\times2\times16.37}{11} = 124.33$$

Using randomized complete block design can reduce the repeated multiples which are

$$R = \frac{(6+1)(8+3)}{(6+3)(8+1)} \cdot \frac{124.33}{16.37} = 7.21$$

This means that using the block design, the numbers of the test repetitions can be greatly reduced, but it is still able to maintain the same error sensitivity.

4. Conclusion

When performance is one of the criteria to select the product components, the use of randomized block design has the following advantages:

The statistical test design theory discusses the number and the relationship of all data in a group of test, can obtain the quantitative measure of the information provided by a testing scheme. Statistical methods allow us to measure the possible errors in the conclusions, or attach the confidence level to a proposition. And the advantage is that it added objectivity to the judgment process can make the test conclusion more accurate.

Using a randomized block design, in implementation of each processing, the differences between conditions can be separated from the difference in the processing, and be separated from the experimental bias. This design is equivalent to subdivide the test conditions into blocks with relatively the same conditions. So it can effectively reduce repetitions of the test, making the test more effective with comprehensive effect of optimum test design and appropriate repeat the number of test. All of that can bring a lot of economic savings for a test workload, and the economic savings can greatly compensate for the additional time and mental labor spent on the design of test experiments.

It can distinguish the impact of bias on the actual performance gap, especially is suitable for the comparison of more than two kinds of different products. Meanwhile, the use of non-statistical knowledge in testing also needs to be considered. Such non-statistical knowledge is extremely important in the aspect that selection of factors, determining the factors level, deciding how many repetitions, and the analyses of result.

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References

[1] Weyuker EJ and Vokolos FI. Experience with Performance Testing of Software Systems: Issues, an Approach, and Case Study. *IEEE Transactions on Software Engineering*. 2000; 26(12): 1147-56.

[2] JH Jiang 20202. *Performance Assessment of Embedded Systems by Benchmarking*. Tongji University, Shanghai 200331,China; Fudan University, Shanghai 200433, China. 2002; (124): 43-8

[3] Ofelt D and Hennessy L. 2000 Efficient Performance Prediction for Modern Microprocessors. *SIGMETRICS*. 2000; 229-39.

[4] Kerbyson DJ, Wasserman HJ and Hoisie A. Exploring Advanced Architectures using Performance Prediction. In: Innovative Architecture for Future Generation High-Performance Processors and Systems. *IEEE CS Press*. 2002: 27-37.

[5] Snavely A and Purkasthaya A. *A Framework to Enable Performance Modeling and Prediction*. In: Proceedings of the 2002 ACM/IEEE conference on Supercomputing, Baltimore. 2002; 1-17.

[6] Box GE and Hunter JS. 1957. Multifactor Experimental Design for exploring response surfaces. *Annals of Mathematical Statistics*. 1967; 28: 195-242. Cochran W G. Analysis of Covariance: Its Nature and Uses. *Biometrics*. 13(3): 261-281.

[7] Ferrari D, Serazzi G, and Zeigner A. *Measurement and Tuning of Computer Systems*. New York: Prentice Hall. 1981.