Resource Usage Evaluation Study in HPC Cluster

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Abstract. In order to evaluate the running state of computing clusters, this paper proposes a measure index for evaluating the resource utilization of nodes in high-performance computing clusters -- Load Score of Computing Node (LSCN), and compares two methods for determining parameter weights, principal component analysis (PCA) and entropy weight determination method (EWD), in combination with relevant algorithms in the field of machine learning, so as to provide useful guidance for the running and maintenance of computing clusters.

1. Introduction

With the explosive growth of information in human society, computer technology, as an important means of information processing, has played an indispensable role in various fields in the past decades. High performance computing (HPC) usually refers to a kind of computing with high running speed and large amount of data. Its powerful computing force enables computing tasks to be completed in a very short period. Of course, it is not enough to only have computing resources, in order to have higher work efficiency, we need to make better use of computing resources.

Due to the high performance computing system user is numerous, how will the user submits the reasonable computing tasks submitted to the various nodes, makes the compute nodes are as much as possible into the working state and not under the heavy load, and make as many users can be satisfactory for complete computing tasks, is a high performance computing system designers and operational problems needed to be considered.

2. Related Works

Mechanisms for allocating, throttling, and optimizing these three key resources in a containerized HPC environment are proposed in [1]. And the performance of three different open source cloud platforms is compared and analyzed [2]. PCA has been widely used in scientific research. PCA is applied in fault detection and classification [3], this problem has something in common with the use of resources in the system. Entropy weight method is also applied to the processing and evaluation of various data. For example, Feng et al [4] used this idea to design a threat assessment model. Xiong et al. [5] also used information entropy to assess the security risk level of information systems. Using this idea for reference, we can also use these algorithms to evaluate the resource usage of the system in the HPC cluster management.

3. Evaluation Index of System Load

To describe the running state of the system, the current running resource information of the system needs to be obtained first. We can use the matrix $D$ to represent the current running state of the system, where $D_{ij}$ represents the $j^{th}$ parameter value of the node $i$. Various indicators are used, but for the convenience of expression and evaluation, we can define a single performance evaluation indicator to
indicate the load condition of the current node. This poses a problem: how to reflect the impact of multiple original indicators in one indicator?

Although each index can represent an aspect of the running state of the system, it is obvious that they can reflect different degrees. Therefore, we need to determine different weights for each index. The greater the weight of the index, the greater the impact on the overall operation of the system. For the weight of the $j^{th}$ index, we have:

$$\sum_{j=0}^{N} w_j = 1$$

For each Computing Node in the system, we define a metric -- Load Score of Computing Node (LSCN). For node $i$, we have:

$$S_i = \sum_{j=0}^{N} D_{ij} w_j$$

Where $S_i$ is the LSCN of node $i$.

Therefore, we need to find a reasonable weighting method, so that the final evaluation index can consider all the indicators of the running state, but also have some emphasis. For example, if a parameter is close all nodes, the weight of that parameter will be relatively small. And vice versa.

This paper mainly compares two weight determination methods: one is principal component analysis (PCA) method and the other is entropy weight determination method (EWD).

3.1. Principal Component Analysis (PCA)
Principal component analysis (PCA) is an effective method to eliminate redundancy and noise in data [6]. It extracts the most important information in data by calculating the eigenvalue of covariance matrix, which can reduce the complexity of data and retain the original data features to the greatest extent. The PCA process of the above original data matrix $D$ is as follows:

1) Centralize the data, that is, calculate the mean of each column, take the mean as 0, use the increase or decrease of the original data relative to the mean as the value of this point, and get the centralization matrix $C$

$$C_{ij} = D_{ij} - \frac{\sum_{i=0}^{M} D_{ij}}{M}$$

2) Find the covariance matrix $V$ according to the centralization matrix $C$. The greater the absolute covariance, the greater the influence on each other and vice versa.

3) Find the eigenvalue matrix $X$ from the covariance matrix $V$.

4) Find the corresponding eigenvector according to the eigenvalue matrix.

5) Sort the eigenvalues and compare them with the set threshold values. If the eigenvalues of an attribute are greater than the threshold values, the attribute can be identified as the main component.

6) The variance contribution value of each attribute is calculated as the weight of the attribute. If the eigenvalue of the $j^{th}$ attribute is $\epsilon_j$, then the weight $w_j$ of the attribute is

$$w_j = \frac{\epsilon_j}{\sum_{j=0}^{N} \epsilon_j}$$

3.2. Entropy Weight Determination (EWD)
Entropy theory can also be used to determine the weight of each index in the data[7]. The lower the entropy of information, the greater the dispersion, the greater the information and the more important the role it plays in the evaluation. The higher the entropy is, the smaller the dispersion is and the smaller the information content is. Therefore, information entropy can be used to measure the impact of features on the final goal.
The steps to determine the weight value of each index by using the information entropy theory are as follows:
1) For the original data of n indexes with m nodes, the decision matrix $D$ can be constituted.
2) $D$ is normalized to get the normalized matrix $R$.

$$R = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix}$$  (5)

In (5):

$$r_{ij} = \frac{d_{ij}}{\sum_{k=1}^{m} d_{kj}}$$  (6)

3) Calculate the entropy of each index.

$$E_j = -\frac{1}{\ln m} \sum_{i=1}^{m} r_{ij} \ln r_{ij}, 1 \leq j \leq n, 0 \leq E_j \leq 1$$  (7)

4) Calculate the dispersion value of each index.

$$F_j = 1 - E_j$$  (8)

5) Calculate the weight of each index.

$$w_j = \frac{F_j}{\sum_{k=1}^{n} F_k}, j = 1, 2, \ldots, n$$  (9)

4. Linear Regression Prediction

Linear regression is a classical algorithm in machine learning. For the two variables with correlation, one of them can be considered as an independent variable and the other as a dependent variable. If the relationship between the two variables can be approximately expressed by a straight line, we can use regression analysis method in mathematical statistics to determine the quantitative relationship of mutual dependence between them. If the independent variable is time, then after determining the quantitative relationship, we can use this relationship to predict the change of the dependent variable.

$$y = wx + b$$  (10)

$$f(x_i) = w'x + b'$$  (11)

The purpose of this learning process is to find $w'$ and $b'$ to obtain the fitting model. Linear regression has the advantages of simple and easy to understand and fast calculation speed. After calculating the predicted value, we can use the actual value of the dependent variable to judge the accuracy of the results.

5. Experiment and Result Analysis

We take a computing cluster as an example to evaluate the load balance of a high-performance computing system. The cluster contains 16 compute nodes. Based on previous analysis of computing tasks on the system, we collected CPU, memory and network bandwidth usage as raw data.

SSH was used to log in to the high-performance computing platform, and the C language-based information acquisition program was written in the Linux environment to collect system resource status information. Then the data processing program was written in Python language to process and analyse this part of information, and the corresponding system load evaluation value was obtained. Some of the computing nodes were selected as the research objects, and PCA and EWD were used for calculation respectively to obtain LSCN score. Then, linear regression was used to calculate the prediction evaluation value of the next two time periods, and the actual measured value was taken as the test set to analyse the accuracy of its prediction. A group of representative nodes was selected in the experiment.
Figure 1. The predicted value and measured value of LSCN under two methods.

At the same time, the evaluation deviation under the two methods is calculated.

Table 1. The Evaluation Deviation

|       | 1st Period | 2nd Period | Mean Error |
|-------|------------|------------|------------|
| PCA   | 0.30       | 0.68       | 0.49       |
| EWD   | 1.53       | 1.77       | 1.65       |

The following figure shows the LSCN values obtained by evaluating some nodes in the cluster with two methods respectively, and the predicted values by linear regression method are compared with the measured values.

6. Conclusions

According to the above experimental results, it is not difficult to find that PCA has better performance in measuring the resource utilization of the computing cluster. In order to make the measurement of system operation more accurate, the cluster manager can introduce more operation status indicators, which will help to predict the possibility of problems in the system and improve the operation stability of the system when improving the utilization of system resources.

7. Acknowledgments

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8. References

[1] Herbein S et al. 2016 Resource Management for Running HPC Applications in Container Clouds. International Conference on High Performance Computing pp 261-278
[2] Li C Y, Xie J Z, and Zhang X J 2014 Performance Evaluation Based on Open Source Cloud Platforms for High Performance Computing. *International Conference on Intelligent Networks & Intelligent Systems* pp 90-94

[3] Yue H H and Tomoyasu M 2005 Weighted principal component analysis and its applications to improve FDC performance. *IEEE Conference on Decision and Control* pp 4262-4267

[4] Feng L Y, Xue Q and Liu M X 2011 Threat evaluation model of targets based on information entropy and fuzzy optimization theory. *IEEE International Conference on Industrial Engineering & Engineering Management* pp 1789-1793

[5] Xiong J S, Li J H and Yang Y H 2012 Method of Determine Index Weight in Security Risk Evaluation Based on Information Entropy. *International Conference on Multimedia Information Networking and Security* pp 43-48

[6] Principal Component Analysis. https://en.wikipedia.org/wiki/Principal_component_analysis

[7] Entropy. https://en.wikipedia.org/wiki/Entropy