Modeling a Datacenter State Through a Novel Weight Corrected AHP Algorithm

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Abstract. Analytic Hierarchy Process (AHP) is an effective algorithm for determining the weight of each module of a model. It is generally used in the process of multi-indicator decision making. But, when using AHP for evaluation, it is inevitable to introduce the evaluator's subjectivity. In this paper, an algorithm based on Bayes' formula is proposed for correcting the weights determined by the analytic hierarchy process. This algorithm can reduce the subjectivity of the evaluator introduced during the evaluation process. At the same time, the common operational indicators of a data center are summarized and classified. I chose some relatively important indicators and established an evaluation model for the operational status of the data center. The weight of the modules of the established model is corrected using this improved algorithm.

Keywords: Analytic hierarchy process · Datacenter indicators
Cloud datacenter evaluation model · Bayes' formula

1 Introduction

1.1 A Subsection Sample

The concept of cloud computing [7] was first proposed by Google CEO Eric Schmidt at the 2006 Search Engine Conference. Cloud computing typically provides computing, networking, storage, and other resources to users on a rental basis. The carrier of cloud computing is a wide variety of cloud datacenters. After decades of development, the traditional computing center has gradually transformed from the traditional "computer room" mode of storing mainframes to the modern large-scale cloud computing center with highly standardized modularization. [8]. With the development of virtualization [9, 10] and other technologies, the datacenter is the key to ensuring that users can use cloud computing anytime, anywhere, like using water, electricity, gas and other resources as a public service infrastructure. Therefore, how to ensure the safe and stable of the data center has become a topic worthy of further study.

At present, the monitoring method of the operation state of the data center generally sets the threshold value for each key indicator, and if the threshold value is exceeded or continuously exceeds the target value within a time window, the operation of alarm will be taken [1]. Haryadi S. Gunawi, Agung Laksono and others classified failures into upgrade, network failures, bugs, misconfigurations, traffic load, cross-service

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dependencies, power outages, security attacks, human errors, storage failures, natural factors, etc. According to the data published by the data center, the frequency and impact of the above faults were statistically analyzed [2]. Dong Seong Kim1, Fumio Machida develops an availability model of a virtualized system using continuous time Markov chains [4].

This paper first summarizes the key operational data indicators of the datacenter. I use principal component analysis [5] to select key impact factors in the monitoring indicators commonly used in datacenters and constructed an evaluation model of the operational status of the datacenter using the Analytic Hierarchy Process [3]. Aiming at the subjective problem of the analytic hierarchy process, I proposed an improved AHP scheme based Bayes' theorem.

2 Cloud Datacenter Operation and Maintenance Indicators

The monitoring indicators of the entire cloud data center are very complex. After a long period of investigation and research, the daily monitoring data of the data center are divided into two categories, which are operation indicators and operation and maintenance indicators. Operational indicators refer to the daily operations of the data center, mainly including tax, site cost, human cost, power cost, water cost and other indicators. The operation indicators are not detailed in this paper. The daily operation and maintenance monitoring of the data center mainly includes eight indicators: moving ring indicators, physical machine indicators, virtual machine indicators, middleware, security, log system, operation and application monitoring, operation and maintenance human management. The indicators and their sub-indicators are listed in Table 1:

Table 1. Operation and maintenance indicators and their sub-indicators

Types	Indicators
Power and environmental indicators	UPS, Distribution Cabinet, Precision air conditioner, Fresh air equipment, Air quality indicators
Physical machine indicators	CPU temperature, CPU usage, Power status, Network bandwidth capacity, Memory usage
Virtual machine indicators	vCPU usage, Network usage, Network throughput, Network delay, Disk operation
Middleware	SQL database, NoSQL database, Message queue, Docker
Log system	Hardware log, Firewall log, Operation log
Safety	Network firewall, Intrusion detection, Gateway monitoring, VPN, Vulnerability scanning

However, building the datacenter operational state evaluation model directly with the above indicators will be to complex. At the same time, the weight of the model components cannot be well determined. Moreover, the calculation work of AHP will increases dramatically with the increase of criteria layer targets. Furthermore, there are also problems of consistency and objectivity when adopting the analytic hierarchy process. In this paper, the principal component analysis method is used to solve the problem of too many targets in the criterion layer, and the consistency evaluation method is used to remove the evaluation matrix when it is inconsistent. The weights obtained by the evaluation are corrected using a weight correction algorithm based on the Bayes' formula.

3 Modeling Process and Method

3.1 Objective Measure

Evaluation with AHP will inevitably disturbed by the subjectivity of the evaluator. Subjectivity can significantly affect the accuracy of the assessment result. Therefore, the key step in the evaluation using AHP is to conduct the consistency test. The process of the consistency check is to calculate the maximum eigenvalue of the evaluation matrix and its corresponding eigenvector. Use the formula.

$$C.I. = (\lambda\_max - n)/(n - 1) \tag{1}$$

$$C.R. = (C.I.)/(R.I.) \tag{2}$$

to calculate the value of C.I. and R.I. Where n is the number of items evaluated. C.I. is the consistency indicator, R.I. is the average random consistency indicator, and C.R. is the ratio consistency [6]. If the value of the ratio consistency is less than 0.1, it is generally considered that the weight vector constructed by the AHP method is reasonable. The consistency test can only indicate that the evaluation is more reasonable for the distribution of each weight, but this does not mean that the evaluation is objective. So how should we define objectivity? In the process of evaluating multiple evaluation indicators of a system, we can assume that the evaluator with complete domain knowledge evaluates each indicator reasonably. In the case of the existence of the objective weight of the indicator i, the subjective weight obtained by the different evaluators (suppose the number of evaluators is k) for the evaluation of the indicator i should obey the normal distribution of the objective weight value. At this point, the process of using AHP to score the indicators can be abstracted into selecting one subjective and most important indicator from the k indicators. We assume that in an evaluation process, the evaluators' subjective degree is the same for each evaluation indicator, that is, the standard deviation of the normal distribution of each indicator is σ.

According to the nature of the normal distribution, the probability that the index i is more important than the index j in an evaluation process is [11]:

$$\left(\int_{-\infty}^{\frac{(w_{iob}+w_{job})}{2}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-w_{iob})^2}{2\sigma^2}} dx\right)^2 \tag{3}$$

The derivation process is omitted here. It is easy to know that (3) is a function related only to w_{iob} and w_{iob}. In the system of promotion to multiple indicators, the probability i is evaluated as the most important probability is $P(w_{iob}, w_{mob})$. Where

w_{mob} is the weight of the objective most important indicator among all the indicators involved in the evaluation. Let event T_i be the indicator A is chosen as the most important indicator in an evaluation process. Then, $P(T_i) = P(w_{iob}, w_{mob})$ is indicator i's weight w_i. That is $w_i = P(T_i)$.

3.2 Weight Correction Algorithm Based on Bayes Formula

Defining that event O is evaluating objectively in an evaluation process, then event $\overline{O}$ is evaluating not objectively in an evaluation process. As can be seen from the above discussion, $P(T_i) = w_i$. Where $P(T_i)$ is a unconditional probability. This means that this evaluation may be objective or non-objective. Then we can calculate the prior probability from the posterior probability. According to Bayes' formula:

$$P(T_i|O) = \frac{P(T_i)P(O|T_i)}{P(O)} \tag{4}$$

$P(O|T_i)$ refers to the objective probability under the premise of obtaining the weight of indicator i. We assume that there is a linear correlation between the consistency indicator C.I. and the objective probability of an assessment. So, $P(O|T_i) = \theta * C.I + b$. Correlation coefficient θ is less than 0. $P(O)$ in the above formula refers to the degree of overall objectivity of an evaluating process, and here refers to the mean probability of objectiveness of all participating evaluators. According to this, the following algorithm can be proposed. Calculate the ratio consistency C.R. for each evaluation matrix and judge whether the value is less than 0.1, and select the evaluation matrix that conforms to the consistency to perform the weight correction. Calculate the weight of each indicator by AHP, and record it as W $(w_1, w_2, w_2 \ldots w_n)$. For each w_i in W use the formula (5) to correct its weight.

$$P(T_i|O) = \frac{w_i * (\theta * C.I. + b)}{P(O)} \tag{5}$$

4 Analysis and Verification

I invite cloud computing service providers, cloud computing experts, and research scholars to evaluate the importance of indicators in A by means of questionnaires. In the end, I collected a total of 23 valid evaluation samples. I use principal component analysis to select the three factors with the highest cumulative contribution rate, namely, power and environmental indicators, physical machine indicators, and virtual machine indicators for algorithm verification. I will record the three indicators taken as a_1, a_2, a_3, and use the 1– 9 scale method to evaluate the three indicators. The detailed meaning of the scale method is listed in Table 2 [5].

Table 2. Importance degree

Difference in importance level	Description of importance degree
1	Equally important
3	Slightly important
5	Obviously important
7	Quite important
9	Extremely important

The evaluation matrix that can pass the consistency test is used as an effective evaluation sample. The weight result calculated by the AHP is shown in Fig. 1. Where the ordinate is the weight of each indicator and the abscissa is the ith assessment:

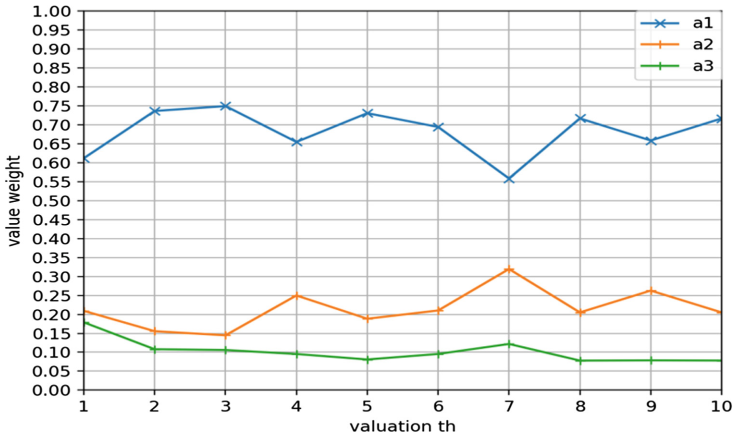

Fig. 1. Raw weight calculated using AHP

The weights obtained after the correction are shown in Fig. 2 (Here, the value of the correlation coefficient θ is –1, and the value of b is taken as 2):

The variance of the raw data of the three indicators a_1, a_2, a_3 is [0.0033899, 0.00238617, 0.00085738]. The variance of the three data processed by the algorithm is reduced to [0.00289193, 0.0028247, 0.00083877], which is reduced by 17.22%, 15.52%, and 2.22%, respectively. The volatility of this three indicators have been reduced to some extent after being revised. According to the discussion above, the less volatility means subjective. This shows that this algorithm effectively reduces the subjectivity in the evaluation of the analytic hierarchy process. Finally, the weights of the three indicators a_1, a_2, a_3 are [0.68200825 0.21602911 0.10196264]. Using these weights can easily constructs a data center model.

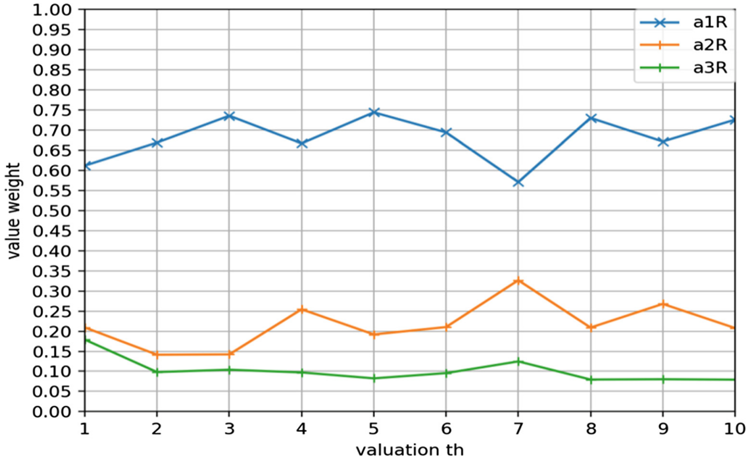

Fig. 2. Weight calculated after using weight correction algorithm based on Bayes formula

5 Conclusion

The availability of cloud computing requires a smooth, secure operation of the cloud data center. This paper first investigates the indicators of cloud data center operation and maintenance, and summarizes the main indicators of the data center. The weights of the individual evaluation factors are determined by using principal component analysis and analytic hierarchy process. At the same time, an algorithm for correcting the weight determined by the analytic hierarchy process is proposed, which can reduce the subjectivity introduced by the AHP method. Through the revised weights, a datacenter operation state evaluation model is constructed.

In this paper, the weight correction algorithm is validated only in the case of three evaluation factors, and no further verification is entered in the case of more indicators and greater volatility of weights. In addition, the values of the parameters θ, b can be determined using a gradient descent algorithm. These related work can continue in the future.

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