Design and Implementation of Status Monitoring System for E-Learning Web Service

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Abstract. This paper is based on the "National Elaborate Course Integration Project", aiming to monitoring the service status of distributed elaborate course web servers across the nation. An evaluation index system is developed and a comprehensive evaluation method is applied to evaluate the web server's connectivity. This paper also proposes a monitoring strategy management method to optimize the regular monitoring. Detailed system design and historical implementation results are provided to prove the feasibility and effectiveness of the system.

Keywords: Elaborate course, status, monitor, evaluation.

1 Introduction

Technological developments like web and internet have profound effects on education [1]. Nowadays, e-learning and distant education becomes more popular and feasible with the help of modern information technology. In 2003, the Ministry of Education of China started the construction of National Elaborate Course and a great number of university-level elaborate course websites have been set up since then. In this way, students get access to high quality study material easily and can communicate with teachers with great convenience.

Although great achievements have been made in e-learning and elaborate courses, there are still some problems to solve. One of these problems is the service quality and stability of websites of elaborate courses. As we know, the websites of elaborate courses is the key channel connecting study material and users all over the country. In the National Elaborate Course Sharing System [2], some of material is in lack of maintainance and the connectivity cannot be guaranteed. This situation leads to waste of education resource and loss of users: For one thing, those high quality materials which have cost big investment cannot be well shared across the country; on the other hand, bad user experience caused by poor service quality will reduce the utilization of elaborate course resource.

In this paper, we aim to monitor the service status of distributed elaborate course web servers and provide a comprehensive evaluation method based on the monitoring

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data. This evaluation result can be used directly in improving user experience and service quality of elaborate course websites. The rest of this paper is organized as follows: Section 2 introduces the evaluation index system and the comprehensive evaluation method of analytic hierarchy process. Section 3 describes the monitoring strategy to optimize the monitoring process and regular schedule. In Section 4, we introduce the design of the java-based monitoring system together with the application effect of this system. Section 5 draws the conclusion.

2 Evaluation Index System and Comprehensive Evaluation Method

A. Evaluation index system

To evaluate the connectivity of those elaborate course websites, we have to first develop an evaluation index system to evaluate different aspects of connectivity [3]. These aspects include availability, connection speed and stability.

The first aspect is availability. It means the success ratio when users try to connect to certain websites. It is the basis of high quality service. If the websites are not available, then it is meaningless to discuss about the quality of the service.

The second aspect is connection speed. Naturally, connection speed can be evaluated by the response time of website. The response time of certain website will have some randomness caused by randomness of the environment. We could use statistic like mean response time to reduce the effect of this randomness. Since we care more about the present connectivity than historical data, we should put more weight on new monitoring data. Assume the speed index is A_i after i times of measuring and the result of the next time is B , then we can calculate A_{i+1} :

$$A_{i+1} = aA_i + (1-a)B, (0 < a < 1) \tag{1}$$

Here a is the weight of historical result and the weight of B will reduce as time goes.

The last aspect is stability. The statistic we used will be useless if the randomness of connection speed is highly random. So we need an index to evaluate the level of randomness. Here we use standard deviation:

$$\sigma(X) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{2}$$

Because the result we get from monitoring is unbiased estimate of standard deviation, we should use sample standard deviation as follow:

$$\sigma(X) = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{3}$$

B. Comprehensive evaluation method

Based on three aspects we mentioned above, we have to provide an overall judgment about the connectivity of elaborate course websites. Before we come to a comprehensive evaluation result, we have to do number normalization [4] and transfer all the indicators to positive indicators with the value between 0 and 1.

Then we use analytic hierarchical process (AHP) for comprehensive evaluation. AHP is a measurement method through pairwise comparison [5]. Here we have already structure the decision hierarchy and construct the pairwise comparison matrix in Table 1.

Table 1. Pairwise comparison matrix of connectivity

	Speed	**Stability**	**Availability**
Speed	1	3	1/2
Stability	1/3	1	1/5
Availability	2	5	1

The numbers in the table indicate the priority between two criteria. This priority relies on judgment of expert and its value range from 1 to 9. 1 means same importance and 9 means the former criterion is extremely more important than the latter one. For example, the number in column 2 row 1 is 3, which means speed is a little bit more important than stability. Consequently, the number in column 1 row 2 should be 1/3 for consistency. We know that pairwise comparison is much easier to human beings than overall comparison. In this way, we can get the weight of different criteria easily.

It can be proved that unified eigenvector corresponding to the biggest eigenvalue $\lambda_{\max}$ of pairwise comparison matrix is just the weight vector of the criteria [6]. Here the unified eigenvector is $W = (0.31, 0.11, 0.58)^T$.

Before we use the weight vector to calculate the comprehensive evaluation result, there is still one job to finish. We use a_{ij} to denote the comparison matrix element on column i row j and use n to denote the matrix dimension. If our judgment on pairwise priority is strictly consistent, then

$$a_{ij} a_{jk} = a_{ik}, \forall i, j, k = 1, 2, ..., \tilde{n} \tag{4}$$

Usually, this equation cannot be strictly obeyed. We have to check the consistency of the comparison matrix. The consistency indicator (CI) can be calculated use

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{5}$$

Then we find out randomness indicator (RI) from Table 2. Here we use 0.58 as n =3. Consistency ratio (CR) is

$$CR = \frac{CI}{RI} \tag{6}$$

Table 2. Randomness indicator for AHP

n	RI
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45

Usually, we regard the comparison matrix as consistent when $CR < 0.10$. In our case, $\lambda_{\max} = 3.0037$, $CI = 0.0019$, $CR = 0.0033$.

3 Monitoring Strategy Management

Monitoring websites' status is something that happens frequently. Due to the large number of elaborate course websites and their heterogeneous technical characteristics, the monitoring efficiency could be largely affected. In order to solve this problem, some methods were proposed in this part to optimize the monitoring process.

A. Monitoring process optimization approach

The optimization of monitoring process mainly consists of three parts.

First, remove from monitoring list those websites which are no longer working according to the statistical data of their reliability. From section 2 we know that reliability plays a very import role when evaluating a website's status. For those websites which are unavailable for a long time, it will make no sense to discuss their response time or stability. For websites which act unconventionally and could not have themselves restored after a period of time, the monitoring program will stop connecting them and invoke some manual intervention. An obvious advantage of this action is that it will reduce the unnecessary waste of time during monitoring.

Second, dynamically adjust the response timeout according to different connection speed. In order to get an accurate result, the response timeout has to be set long enough. As a result, during the monitoring process, we found that most of the time was wasted on waiting for the response of websites not available. One obvious fact is that, it is unreasonable to set the same response timeout for a website whose average response time is 10 milliseconds and for another whose average response time is 10 seconds. So here we propose another strategy: Dynamically adjust the response timeout for a website according to its statistic of response time. For example, we could use average response time plus standard deviation as response timeout. Also we usually set a lower limit of timeout in order to increase the monitoring accuracy.

Third, dynamically determine the monitoring frequency of a website according to its stability. Among the websites which are monitored, we found some of them had very stable response time. For this kind of websites there was no need to measure their response time frequently. Here the stability of a website is not indicated by standard deviation of response time, but by the ratio between stand deviation and mean value.

B. Application effect

We carried out an experiment on 10 websites. Table 3 shows the response time we got from these websites. From the result we see that after optimization, the total response time added up to 250 milliseconds, compared to the response time of 10765 milliseconds (website 2 was in fact unavailable) before optimization. After applying the optimized strategy, different websites would have different monitoring frequency, so some of the websites tested were not monitored (marked with “-”). The monitoring efficiency is significantly increased in two ways: First, the number of websites to be monitored each time is reduced; second, the long time wasted on unavailable websites is avoided.

Table 3. Result of different monitoring strategies

No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Before	0	10^4	16	172	0	187	15	16	16	343
After	15	-	-	-	15	188	-	16	-	16

The unit here is millisecond.

4 System Design and Implementation Result

In this section, we will describe the design of the monitoring system and then briefly present the implementation result.

Fig. 1 shows the function flow of the system. Data recording and analyzing stand in the center of the functions.

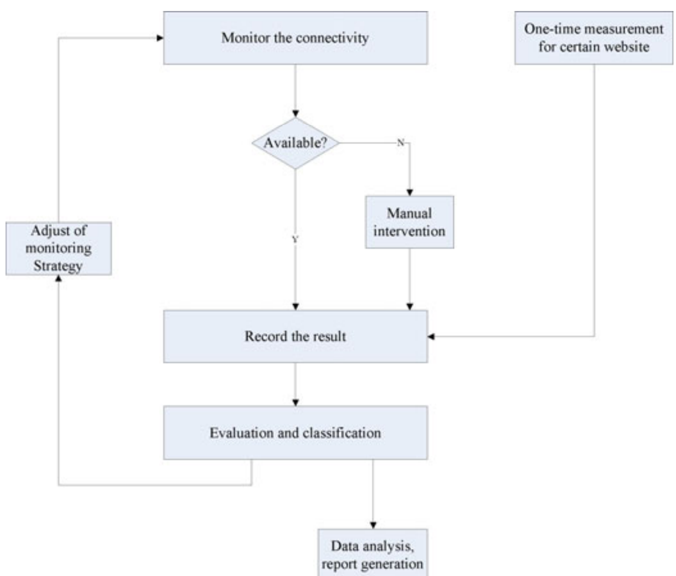

Fig. 1. Function flow diagram of status monitoring system

Basically there are two different ways of data acquisition. The first one is one-time measurement for certain website. System administrator can access this function through web-based management platform and he can choose whether to put the result into database. The second way is regular monitoring through java-based application. If there are any exceptions when monitoring, manual intervention can be invoked to improve the availability and service quality of websites.

After data recording, the system evaluates and classifies all the elaborate course websites through historical records. The evaluation result is then used to adjust the monitoring strategy to improve efficiency. Statistical report can be generated when necessary.

The architecture of the whole status monitoring system is showed in Fig. 2. It can be divided into 4 tier including supportive bottom tier, data tier, logic tier and appearance tier. The supportive tier provides fundamental hardware and software environment like data base, monitor server, network and monitor module. The data tier contains all historical monitoring data acquired from lower tier which can be used in evaluation and analysis. It is the bridge between supportive tier and logic tier. The logic tier is the core of the whole system. Its main job is data processing, calculating and optimization action. The last tier is appearance tier, by which the users and administrators access and manage the monitoring system. And the system should be in good network environment and connected to distributed elaborate course websites all across the country.

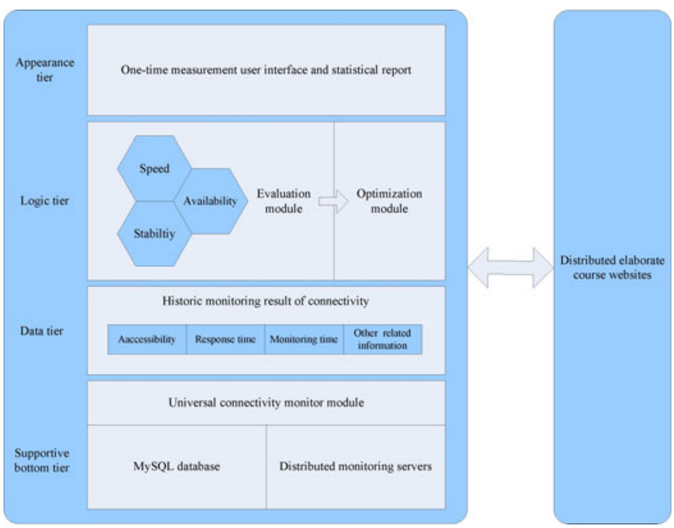

Fig. 2. Architecture of status monitoring system

We started running the monitoring system since 2008 summer. Meanwhile, our system provides search and navigation function for elaborate courses and their websites. The service quality of different websites is partially revealed to users. Now there is information of around 4000 elaborate courses in our system and most of them have their own websites. These websites have got over 1,222,000 clicks totally from our system. And our search function receives 1,240,000 search requests from 163,000 different IP addresses.

We can also see that websites with good performance got more clicks. Here we pick three national elaborate courses with the same course name and denote them as A, B and C. The historical monitoring data is showed in Table 4.

The response time in Table 4 is the mean value of the measurement data of recent 10 times. Obviously, course A got more clicks as its connection speed is the most fast among three courses.

Table 4. Historical data of elaborate course websites

Course	Clicks	Response Time/ms
A	1653	18.70
B	771	407.80
C	1023	88.90

From above discussion, we see that our system regularly monitors the status of elaborate course website and helps to improve the service quality. And the implementation effect is positive.

5 Conclusion

From the practice of National Elaborate Course Integration Project, we see that monitoring service status of websites is very important for improving the quality of elaborate course construction and utilization of education resource.

We developed evaluation index system including availability, stability and connection speed based on real requirement and engineering practice. In order to provide a comprehensive evaluation result of websites' connectivity, AHP is used in the system. Also, we design several optimization methods for high efficient monitoring. These methods are applied in our system implementation.

In the future, further challenges should be conquered. First, the evaluation index system could be improved to better reflect the real status and service quality of certain elaborate course website. For example, web traffic is indicator of the popularity of websites and it can reflect the service quality from other side. But it needs further work to monitor web traffic. Second, the monitoring system faces the risk of single point failure in monitoring servers and related network. More distributed servers should be set up and different statistical results from these servers have to be integrated.

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