Application Research of Artificial Neural Network in Network Attached Optical Jukebox

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Abstract

In this paper, a new measurement method of analyzing performance for Network Attached Optical Jukebox is presented by means of linear neural networks. Through analyzing one operation(request) process in this system, the mathematics model is built for this storage system, then a method based on linear neural networks for this system is proposed. Simulation results testified the feasibility and validity of the proposed method, it could overcome the drawbacks of the bigger random error and the lower resolution in the cross correlation way, and make an effective means for analyzing Network Attached Optical Jukebox.
Keyword: Network Attached Optical Jukebox, linear neural networks, network storage, hierarchical storage.

I. Introduction

The development of the digitalized information and the enhancement of the ability to explore the nature make it necessary for storage systems to store the increasing mass data produced in research experiments.

As the high-capacity and low-cost optical discs with long media life are proper media to store the long-term historical experiment data, it is significative to explore the techniques of using optical storage devices in mass storage system. However, due to the relatively low access performance, it is difficult for the optical jukebox to meet the demands of high performance and scalability of the mass storage system. It is necessary to study the technologies and methods to improve the performance of jukeboxes used in the mass storage system [1, 2].

A new approach of network attached jukeboxes that have mass disk buffer in them and can be accessed directly from network in the mass storage system is presented by OMNERC [3, 4, 5].
With the introduction of the data in the disk buffer, the data in the hierarchical mass storage system are partitioned into four classes: on-line data, quasi-on-line data, near-line data and off-line data. Research shows that the quasi-on-line data in the disk buffer is helpful to improve the performance of network attached jukeboxes by reducing the operations of the jukebox. The amount of data migrated in the network and the migration time can also be reduced by the introduction of the quasi-on-line data.

For a data storage system, the storing capacity, access speed, safety, dependability etc. are all very important. The optical jukebox is a way of massive information storage. Because of its big capacity, high safety, high credibility, is used more and more widely [6,7]. The appearance of the Network Attached Optical Jukebox (NAOJ) [3] had put optical jukebox and network storage together. The principle diagram of this system is show in Fig.1.

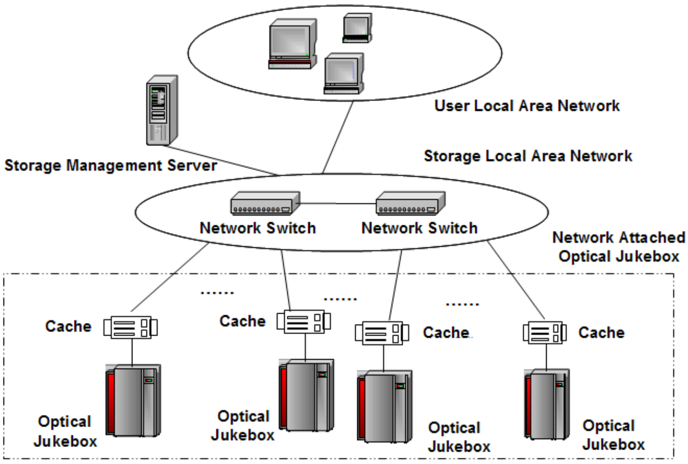

Fig.1 The principle diagram of Network Attached Optical Jukebox

NAOJ, which combined the storing technique of the optical jukebox system technique and networks commendably, is a kind of near line storage system, not real on-line storage system. It adopted a new scheme that treats the optical jukebox as the equipment of NAS connected into the IP Ethernet [8, 9, 10, 11].
It consist of optical jukebox, buffer cache, the network interface of NAS, and so on. NOAJ has several desirable performance, such as high throughput, dependable storage and intelligent management.

II. Open Queuing Networks Model for NAOJ

The storage model of NAOJ is consist of network service module, magnetic disk cache module and optical jukebox module, the framework is show in Fig.2.

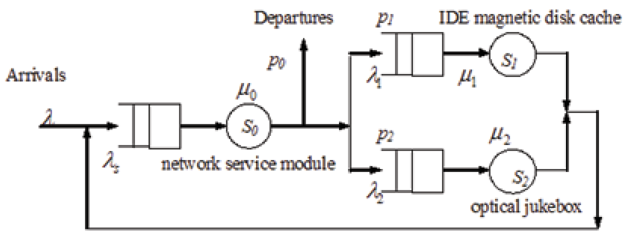

Fig.2 The queuing model for Network Attached Optical Jukebox

For one operation(request) from I/O port, the network service module needs to complete two actions receiving user request and seeding required data to user [12], and NAOJ will complete following steps for each request.

1. When request is received by network service module, the storage manage server will choose magnetic disk cache or optical jukebox to gain service according to location of required data;
2. Check whether the data I/O requests required are in the cache of NAOJ. If yes, then directly read data from disks and submit them to the network service module under the controller' control. Then go to Step4; Otherwise, continue execute Step3;

3. If requested data are in the optical Jukebox, then send the I/O requests to NAOJ controller, the controller access the disc and send the read data to network service module;
4. Network service module send users requested data to users through specified network ports.

Since the response time of magnetic disk is much shorter than that of optical jukebox. This strategy will help to improve the performance of the entire system. The algorithm used in disk cache is very important, and Fig.3 shows the principle diagram which is used for NAOJ.

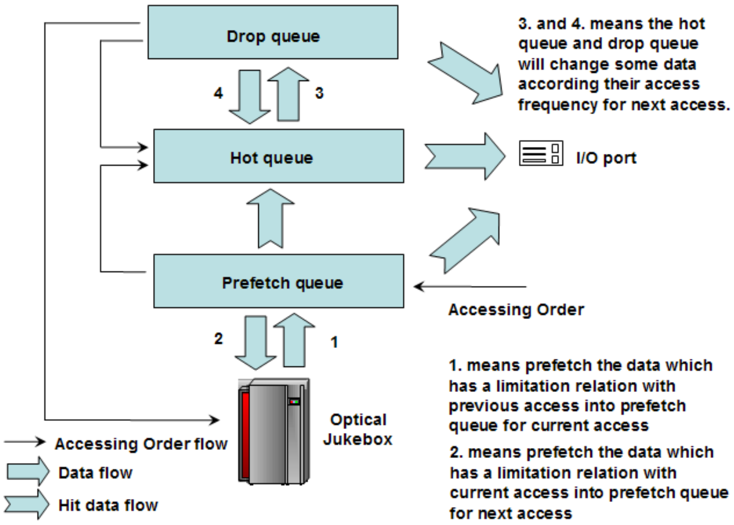

Fig.3 The algorithm flow chart for Network Attached Optical Jukebox

In purpose of simplifying the analysis, we temporarily ignore the effect of scheduling strategy provided service for NAOJ in the process of queue model analysis and assume that all the users' requests obey the FCFS service rules when they are waiting for service in the queue.
In addition, Jackson network model condition has been satisfied simultaneously. So we can take it as open queuing networks with three service nodes for model and analysis [13, 14]. The nodes state diagram is shown in Fig.4.

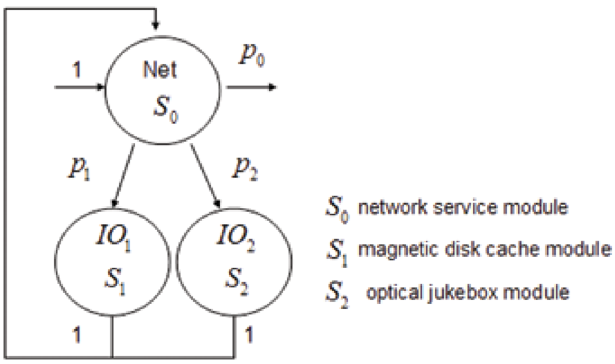

Fig.4 The nodes state diagram for Network Attached Optical Jukebox

In Fig.4, S_j is the probability of users request shift from service node S_0 to the next service node service request node i. is the probability of departure from the service node S_0.
Using the approach of common Markov Chain Analysis, it can be derived that the sum of them is 1. i.e. for NAOJ, the following relation come into existence:

$$\sum_{j=0}^{2} p_j = 1$$

In queuing networks of NAOJ, S_0 and S_2 can be regarded as an individual M/M/1 queuing center, while S_1 is a M/M/2 queuing center.
In the NAOJ queuing network model, let the time intervals of the requests for each node follows the negative exponential distribution parameterized by λ_i, and the customer's requests is follows the negative exponential distribution parameterized by λ.
The service rate of each service nodes is μ_i, average service time is $1/\mu_i$, thus for single service station nodes, their correspondence intensity is $u_i = \frac{\lambda_i}{\mu_i}$.

The correspondence intensity of service station with N_s nodes is $u_i = \frac{\lambda_i}{\mu_i N_s}$.

According to queuing theory, it is easy to find out the requests distribution of each node.

$$\lambda_0 = \frac{\lambda}{1 - p_1 - p_2} = \frac{\lambda}{p_0} \qquad \lambda_1 = \frac{\lambda p_1}{p_0} \qquad \lambda_2 = \frac{\lambda p_2}{p_0}$$

So we can derivate the service intensity for each node is

$$\rho_0 = \frac{\lambda}{p_0 \mu_0} \qquad \rho_1 = \frac{\lambda p_1}{p_0 \mu_1} \qquad \rho_2 = \frac{\lambda p_2}{p_0 \mu_2}$$

Then according to the Jackson theorem and Little formula, we can find the M/M/1 requests number q_i for S_0 node and S_2 node.

$$q_i = \frac{\rho_i}{1 - \rho_i} \qquad i = 0, 2$$

The node S_1, which is a M/M/2 queuing center, is different from S_0 node and S_2 node. According to the state map for M/M/2 queuing center, the following formula can be derivated.

$$q_1 = 2\rho_1 + \frac{\rho_1^3 \eta_0}{(1 - \rho_1)^2} = \frac{2\rho_1 - \rho_1^3}{1 - \rho_1^2}$$

Here

$$\eta_0 = \frac{1 - \rho_1}{1 + \rho_1}$$

Base on the former derivation, it is easy to find out the average response time of each node when every input arrive to the system.

$$T_{qi} = \frac{q_i}{\lambda_i} = \frac{1}{\mu_i (1 - \rho_i)} = \frac{V_i}{\mu_i - \lambda V_i} \qquad i = 0, 2$$

$$T_{q1} = \frac{q_1}{\lambda_1} = \frac{4\mu_1}{4\mu_i^2 - \lambda^2 V_i^2} \qquad i = 1$$

Here

$$V_i = \begin{cases} \frac{1}{p_0}, & i = 0 \\ \frac{p_i}{p_0}, & i = 1, 2 \end{cases}$$

So the response time in this queuing network is the sum of response times in all individual queues, that is

$$T_q = \sum_{i=0}^{2} T_{qi}$$

III. The linear neural network design of NAOJ

Artificial Neural Networks (ANN) is the network established by software or hardware approach. It consists of a large number of processing units as nodes and processing units interconnected with each other with weight. ANN introduces the neural physiology concepts such as neuron, transmembrane potential etc. and replaces symbolism computer patterns with parallel and distributed patterns [15, 16].

Linear neural network ,the most simple neural network, using Widrow - Hoff training rule ,has very high training speed and can not come into local minimum. Fig.5 shows the structure of single-level neural network. The LMS(Least Mean Square Error) learning rule has been adopted, which is similar to perceptron learning rule. For each input vector, the network compute output vector and compute the error between output vector and corresponding input vector. Then it regulates the weights and thresholds so that the error decreases gradually.

The performance index of LMS learning rule is a bivariate equation, which minimizes the network training error based on negative gradient descent criterion.

Here, α means learning rate,which is very important. It affect the stability of whole system in learning process. If the learning rate is bigger, the final result may be unshrinking, while the learning rate is smaller, the process will need more time and other problem. In this paper, we let α equal to 0.5.

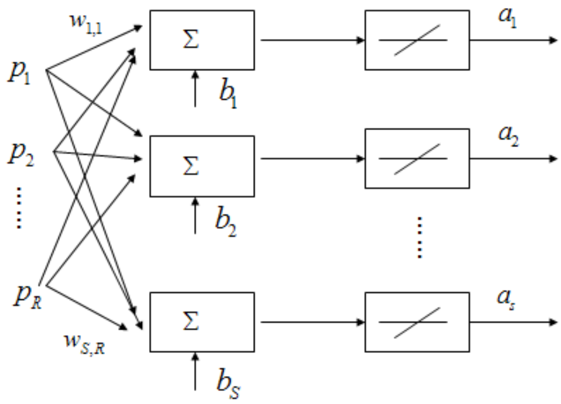

Fig.5 The structure of single-level neural network

If the active functions are nonlinear, we will pretreat the experiment data, the basic method is like BP algorithm. When nerve cell have saturated nonlinear, we must restrict the output value of the nerve cell which are connect with this exceptional nerve cell. Because the function of the input layer is transport data, use the linear function usually. So in order to linearize the active functions. we take the following linearization method in this paper.

$$P_{\max} = \max\{P\} \qquad T_{\max} = \max\{T\}$$

$$P_1 = \frac{P}{P_{\max}} \qquad T_1 = \frac{T}{T_{\max}}$$

Here, P means input, T means output, P_1 and T_1 mean the experiment data after linearization.

For any user waiting in the queue, what he/she cares about is the time interval from his/her entering the system to system finishing his/her service, i.e. the response time of NAOJ system to him/her.

If this time interval is too long, then user can choose other NAOJ to get service. So it seems to be very important to users that system predict next response time according to former response time.

For the NAOJ as a whole, it can be seen according to former derivation that NAOJ' response time is approximately linear with user arriving rate. At the same time, If learning rate is sufficient low, sum of MSE (Mean Squared Error) can be minimized according to result of NAOJ itself. This is because that shape of the error is similar to a multi-dimension paraboloid. It always has a minimum, while using LMS rule can nicely ensure that network training error is able to reach this minimum. So we can use linear neural network to simulate it.

At the same time, the choice of learning rate affects the response time of NAOJ greatly. If learning rate is sufficient low, network training error can reach its minimum according to LMS rule, but comparatively long training time is required. If learning rate is comparatively high, training time can be reduced, but it readily result in decrease of network stability and increase of training error.
Fig.6 and Fig.7 have shown the comparative result of the simulated one and the real one under different drives.

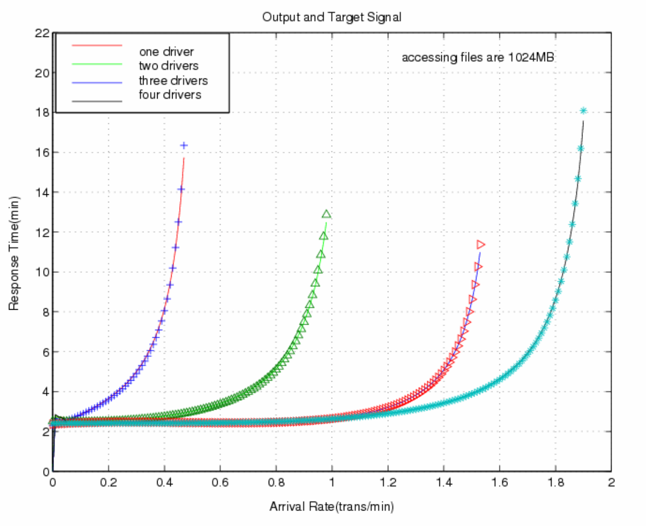

Fig.6 Output and Target Signal

As Fig.6 shows, in the same arrival rate, with the number of drivers increase, the response time of whole system is reduced.

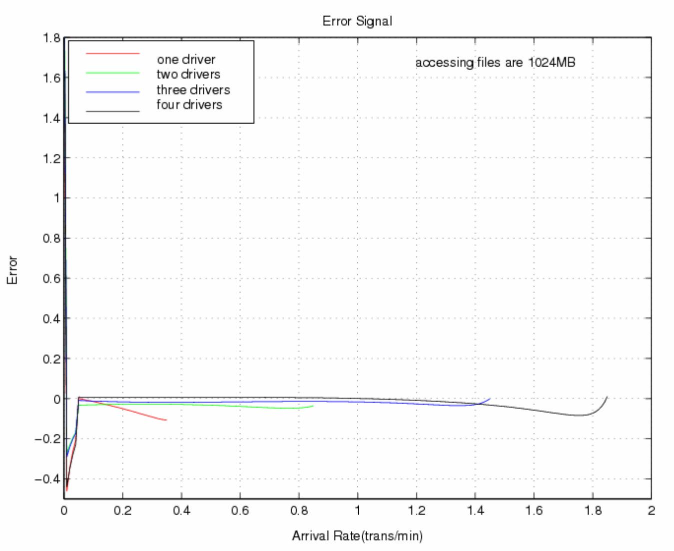

Fig.7 Error Signal

The error signal is shown in Fig.7. Because the number of iteration times are so few, the error signal vary intensely at first, however, with the number of iteration times increase, the error signal became reposeful.
So from the figure, we can see the predictive value is quite near to real one. This is of great importance to guide users to optimize their accesses.

IV. Conclusion

In this paper, we have done extensive research on the NAOJ model on the basis of the existing open queuing network model. Aiming at the service time which single users cares about, we have analysed and given solutions. Resorting to linear neural network, we have conducted simulated experiments on the performance of optical jukebox and NAOJ in the case of different number of drives and predicted the distribution of response time. Our work not only provides guidance for users' accesses and theoretic basis for the analysis of the system performance, but also lays a foundation for further improvement of NAOJ system performance.However, in order to analyse system performance more accurately, we will adopt BP neural networks in the future work.

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