

Forecasting software aging of service-oriented application server based on wavelet network with adaptive genetic algorithm

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Abstract—Web services are gaining acceptance as a standards-based approach for integrating loosely coupled services. Achieving high levels of reliability and availability of service-oriented application server in spite of service or infrastructure failures poses new challenges. According to the characteristic of performance parameters of service-oriented application sever, a new software aging forecasting model based on wavelet network is proposed. The dimensionality of input variables is reduced by principal component analysis, and the structure and parameters of wavelet network are optimized with genetic algorithm and evolutionary programming. The objective is to observe and model the existing systematic parameter data series of service-oriented application server to forecast accurately future unknown data values. By the model, we can get the aging threshold before application server fails and rejuvenate the application server in autonomic ways before observed systematic parameter value reaches the threshold. The experiments are carried out to validate the efficiency of the proposed model and show that the aging forecasting model based on wavelet network with adaptive genetic algorithm is superior to the BP neural network model and wavelet network model in the aspects of convergence rate and forecasting precision.

1. INTRODUCTION

Web services can integrate and collaborate with various applications in a loosely coupled way to achieve business goals. It also decreases the complexity of application connection in order to decrease the cost of maintenance and updating. So it is one of the most promising solutions in web application environment [1]. As more and more applications are built on web services, providing reliable web services is becoming an important issue [2]. Recent studies have reported the phenomenon of software aging [3,4] in which the state of system performance degrades with time. This may eventually lead to performance degradation, crash/hang failure, or other unexpected effects. Aging has not only been observed in software used on a mass scale but also in specialized software used in high-availability and safety-critical applications. In order to enhance system reliability and performance and prevent degradation or crash, such a preventive maintenance technique called software rejuvenation was introduced [4]. For optimizing the timing of such a preventive maintenance, it is important to detect software aging and forecast the time when the resource exhaustion reaches the critical level.

In the area of networks computing, an application server is the supporting and runtime platform of web services. And the dynamic characters of Web service affect systematic behavior and runtime state of an application server. We study the reliability of web service that run in the platform of application server to see whether the service-oriented application server suffers from software aging or not. Our final objective is to forecast software aging of service-oriented application server and then take preventive maintenance technique such as software rejuvenation to improve higher reliability and availability of application server, thus it will leads to lower maintenance cost and more reliable web services that are under the effect of software aging.

2. SOFTWARE AGING FORECASTING MODEL OF SERVICE-ORIENTED APPLICATION SERVER

JVM heap memory usage, the most important resource parameter of service-oriented application server, is forecasted using wavelet network. The impact factors of JVM heap memory usage are considered as input variables. From the complexity viewpoint, it would be required to reduce the number of input nodes to an appropriate minimum. Thus principal component analysis is firstly used here to reduce the number of impact factors and keep the accuracy of forecasting model. Then the primary components are forecasted using wavelet network. Figure 1 illustrates the basic design schema of wavelet network.

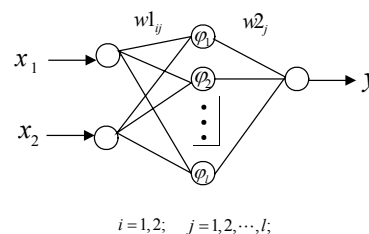


Fig 1. Wavelet network schema

where y denotes the amount of JVM heap memory usage, x_1 is response time and x_2 is throughput amount.

The genetic algorithm is adopted in wavelet network model to help search the optimum number of hidden nodes and parameters of neural network and overcome the problem of convergence towards local optima. The main steps of training wavelet network with adaptive genetic algorithm are as the following algorithm 1.

Algorithm 1. Adaptive Genetic algorithm for training wavelet network aging model

1. Input data and generate chromosome coding of initial population $G(0)$ at random, and set $i=0$;
2. REPEAT
 - a) Use iterative gradient descent-based method training wavelet network parameters, compute the fitness value of each individual;
 - b) Sort the individual of the population in descent order according to corresponding fitness value;
 - c) Set n is the number of individuals will be selected as parents from the population $G(i)$;
 - d) The new generation $G(i+1)$ evolves from the population $G(i)$ by genetic operator, and the genetic operation procedure is as follows:
 - i) Randomly select two parents with higher fitness value from top n individuals of the sorted population;
 - ii) Calculate the crossover probability p_c and mutation probability p_m ;
 - iii) Apply crossover operation and mutation operation based on evolutionary programming to generate the offspring of the two selected parents with probability of p_c and p_m separately;
- 3 UNTIL termination criterion is satisfied or generation number reaches the given maximum generation number.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

The experimental platform simulates a monitoring and recording system for an application server. As in the figure 2, the experimental environment consists of a J2EE application server, clients and database server. In the client, the load generator is used to generate web service requests to the application server through standards-based HTTP and web service protocols. The application server connects and queries database server, and then returns results to clients. By load generator model and resource monitor model, the dynamic parameters in clients and application server are periodically monitored and recorded in a certain format separately.

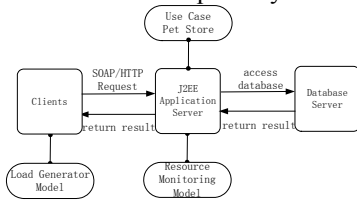


Fig.2 Experimental setup schema

Figure 3 displays the forecasting data for one-step forward forecasting model of JVM heap memory usage and the error between original data and forecasting data. We can see application server performance decreases with time. Table 1 presents approximation performance based on wavelet network with adaptive genetic algorithm model compared with wavelet network and neural network model. The table is shown that forecasting precision of wavelet network with adaptive genetic algorithm model is superior to wavelet network and neural network.

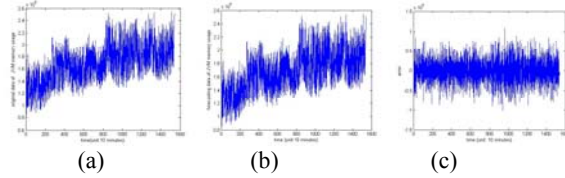


Fig.3 One-step forward forecasting JVM heap memory usage (a). Original data, (b). Forecasting data, (c). Error between original data and forecasting data

Table 1. Comparison of approximation performance

Models	Number of hidden nodes	NMSE
Wavelet network with adaptive genetic algorithm	28	0.0267
Wavelet network in reference [5]	35	0.0374
Neural network in ref [5]	50	0.0498

4. CONCLUSIONS AND FUTURE WORK

The effectiveness of wavelet network with adaptive genetic algorithm for aging forecasting has been investigated. The original time series is preprocessed by primary component analysis. Then the primary components are forecasted by means of wavelet network and an algorithm of back-propagation based on adaptive iterative gradient descent method with genetic algorithm and evolutionary programming is proposed for wavelet network learning. It is important to forecast the critical resource usage such as memory usage for service-oriented application servers. Software aging can be detected and the aging threshold before server crashed can be evaluated using the forecasting model. Thus the reliability of web services is improved when the availability of its running platform such as an application server increases. Future work includes the aging forecasting model considering more causations of resource.

ACKNOWLEDGEMENTS

The author would like to thank the sponsors of the National Natural Science Foundation of China under Grant No. 60473098 and IBM CRL Joint Project.

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