Back-Propagation Neural Network for QoS Prediction in Industrial Internets

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Abstract. As it is well known that QoS play an important role in industrial Internets. However, existing prediction methods failed in obtaining accurate QoS prediction results. Hence, in this paper, we proposed a high accurate approach for QoS prediction for industrial Internets. The key idea of this approach is to adopt back-propagation neural network to predict the QoS data. We implement our approach and experiment it based on a real-world QoS dataset. The experimental results show that our proposed approach can perform accurate QoS prediction results.

Keywords: Web service · QoS · BP neural network · Industrial internet

1 Introduction

With the rapid development of industrial Internet and the quick growth of the service number, service users have to face the massive candidate services which are functionally identical but different in non-functional properties. Due to the huge number of candidate services, service user cannot try all services to select the best one. So, how to choose the best service to satisfy the quality requirement of users is a significant concern for successfully building service-oriented applications [1]. As it is well known that quality of services (QoS) plays an important role in industrial Internets, it becomes a differentiating aspect for functionally equivalent services. Recently, many scholars argue that the QoS values of service cannot be easily acquired from the service provider or the third-party organizations. Therefore, it becomes a significant challenge to acquire the QoS value accurately.

In recent years, extensive research work have been conducted on QoS value prediction. Among them, collaborative filtering techniques are widely used. The main idea is to identify similar users and collect their useful QoS information to the active user. These approaches are based on the hypothesis that all user's value are trustworthy and the evaluation criteria are unified. In reality, some user's QoS values can be untrustworthy and the evaluation criteria may be diversified in industrial Internet [2]. So, many of the existing approaches failed in obtaining accurate QoS prediction results.

In this paper, we proposed a highly accurate approach for QoS prediction for industrial Internets. The key idea of this approach is to adopt back-propagation (BP) neural network to predict the QoS data. Through experiments based on the real dataset, our

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approach achieves good performance in terms of prediction accuracy. The remainder of this paper is organized as follows: In the next section we provide a detailed overview of the related works. Section 3 illustrates our prediction approach based on BP neural network. Section 4 presents experimental results. Finally, conclusions are provided in Sect. 5.

2 Related Work

The study on QoS plays an important role in Service-Oriented Computing domain. Thanks to the development of industrial Internet, many QoS-based issue have been discussed in recent literatures, covering the topic of service selection [3, 4], service composition [5, 6] and service recommendation [7–9].

From the aspect of supporting QoS-based service selection and composition in industrial Internet environments, researchers employ various forecasting technologies for Web services QoS prediction. Lo et al. [3] proposes an extended Matrix Factorization (EMF) framework with relational regularization to make missing QoS values prediction in service selection. In [4], the authors propose a Web service selection approach based on QoS estimation. Their aim is to perform accurate QoS estimation and alleviate the deviations between requiring and receiving QoS in Web service selection.

Recently, many QoS-based recommendation approaches have been put forward. For example, Kuang et al. [7] proposed a personalized service recommendation mechanism based on context-aware QoS prediction. In [8], the authors accomplish the QoS prediction by using fuzzy clustering method with calculating the users' similarity. In [9], the authors propose a novel landmark-based QoS prediction framework and then present two clustering-based prediction algorithms for Web services.

In addition, there are a number of studies about QoS value prediction [10] and QoS ranking prediction [11–16]. However, existing prediction methods failed in obtaining accurate QoS prediction results. In this paper, we proposed a highly accurate approach for QoS prediction for industrial Internets.

3 Our QoS Prediction Approach

In order to obtain higher prediction accuracy, we consider to employ the performance of web service to predict the QoS value. The value of QoS can be determined by multiple service attributes, and different service attributes correspond to different QoS values. Hence, QoS prediction is essentially a problem of multi-target recognition. BP neural network is one of the most popular methods for multi-target recognition. So, we employ BP neural network to predict the QoS value. The specific approach is described as follows.

3.1 BP Neural Network

The BP neural network algorithm is a multi-layer feed forward network trained by error back propagation algorithm. It is one of the most widely applied neural network models.

BP neural network can be used to learn and store a large number of input-output model mapping relations, and there is no requirement to disclose in advance the mathematical equation that describes these mapping relations. Its learning rule employs the steepest descent method in which the back propagation is used to achieve the minimum error sum of square by regulating the weight value and threshold value of the network.

The application of the standard BP network model is converted to a mathematical optimization problem. BP learning algorithm is a global optimization approach, which has a good generalization ability and resilient fault tolerance. The BP neural network has been an important tool to investigate prediction problems due to robust learning ability.

3.2 Constructing Prediction Model

The web service in the industrial Internet may have many attributes, such as response time, availability, throughput, and so on. These attributes jointly determine the value of QoS. Hence, we can determine the mapping relationship between the service attributes and QoS value. Based on this, we design the prediction model as described in Fig. 1. The BP neural network consists of three layers, the input layer, the hidden layer and the output layer.

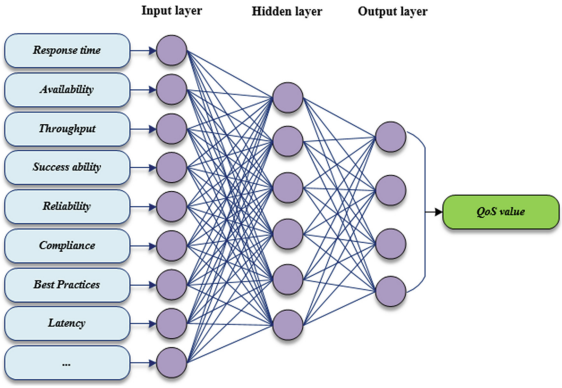

Fig. 1. QoS prediction model based on BP neural network

The input layer contains n nodes, and each node represent an attribute of a service. The output layer contains q nodes, representing q kinds of QoS values, respectively. We can obtain the relevant parameters of BP neural network by the training data, so as to complete the prediction of QoS value. Hence, the core problem of prediction is transformed into the model training problem.

3.3 QoS Value Prediction

In order to predict the QoS value accurately, we first need to train the BP neural network model to get the appropriate parameters. Then, we can predict the QoS values by the trained BP neural network model.

When the BP network is constructed, we can determine the number of weights and bias based the number of input layer, output layer and hidden layer. The input-output problem is transformed into a non-linear mathematical optimization problem. The optimization goal is to find a set of weights and bias to make the global sum of the absolute error between the desired output and the predicted output reach to the lowest point. So we define the fitness function as follows:

$$F = \frac{1}{2\mathrm{m}} \sum_{k=1}^{m} \sum_{o=1}^{q} (d_O(k) - y_o(k))^2,$$

where m is the number of samples, q is the number of output layer, $d_O(k)$ and $y_o(k)$ are the desired output and the predicted output of the k-th sample for the node o in BP network.

The BP neural network employs the steepest-descent method to solve the optimal problems, in which back propagation is used to achieve the minimum error sum of the square by regulating the weight value and a threshold value for the network. After training, the prediction model was set up. The QoS value for any unknown service can be obtained through the trained prediction model.

4 Experimental Study

In order to verify the performance of our approach, we implement our approach and experiment it based on a real-world QoS dataset.

4.1 Experimental Setup

We implemented experiments employing matlab 8.3 on IBM server with Inter Xeon E5-2670 eight-core 2.60 GHz CPU and 32 G RAM. Publicly available Quality of web services dataset (QWS) [17] is used for QoS prediction employing BP neural network model. Services in QWS dataset have four QoS values: (1) platinum (high quality); (2) gold; (3) silver and (4) bronze (low quality). The QoS prediction is based on the overall quality rating provided by WsRF. In the experiment, services are divided into two parts. One is the training data, and the other is the test data.

4.2 Metrics

In our experiment, Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) metrics are used to evaluate the accuracy of prediction. MAE is defined as: $MAE = \frac{1}{N}\sum_i |R_i - \hat{R}_i|$, And RMSE is defined as: $RMSE = \sqrt{\frac{1}{N}\sum_i (R_i - \hat{R}_i)}$, where R_i denotes the QoS of service i, $\hat{R}_i$ represent the predicted QoS value of service i, and N is the number of all predicted values.

4.3 Comparison and Performance

In order to observe the performance of our approach, the Item Mean (IMean), the Naïve Bayes (NB) algorithm, the k-nearest neighbor (KNN) algorithm are chosen for comparative analysis. According to the dataset, we set the input layer number $n = 9$, the hidden layer number $p = 6$ and the output layer number $q = 4$.

Figure 2 shows the MAE and RMSE of the different methods. Obviously, our proposed BP neural network approach is the best both in MAE and RMSE, 0.373 and 0.594 respectively. And the corresponding prediction accuracy is the best. Hence, we can conclude that it is a promising way to improve the accuracy of QoS prediction.

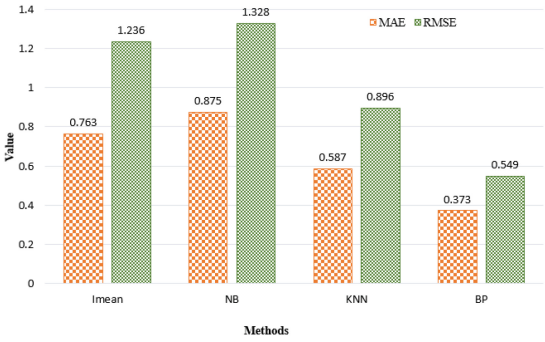

Fig. 2. MAE and RMSE of different methods

5 Conclusion

In this paper, we propose a BP neural network model to improve the QoS prediction accuracy. The mapping relationship between service attributes and QoS value is employed, and modeled by BP neural network. Experimental results demonstrate that our approach can obviously improve the QoS prediction accuracy. In the future work, we will take the context information into consideration to improve the QoS prediction accuracy.

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