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IgS-wBSRM: A time-aware Web Service QoS monitoring approach in dynamic environments

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ABSTRACT

Context: Quality of Service(QoS) is an important criterion to measure the quality of third-party web services. However, it is always affected by different environmental factors. Consequently, how to monitor web service QoS timely and accurately in dynamic environments is an important problem.

Objective: Our article aims to design a novel Web service QoS monitoring approach which can be used in dynamic environments.

Method: To achieve the above objective, we propose a novel weighted naïve Bayesian runtime monitoring approach based on information gain theory and sliding window mechanism, called IgS-wBSRM. IgS-wBSRM initializes the weights of different environmental factors according to training samples collected. Then, according to information entropy and information gain theory, IgS-wBSRM reads the sample data flow in sequence, and calculates the information gain of each environmental impact factor after the arrival of new sample. It updates the initialized weights with TF-IDF algorithm in dynamic environments. In this way, IgS-wBSRM can correct the delay judgement, jitter noise and off-line constant problems in traditional monitoring approaches. Furthermore, considering the timeliness of the training samples, IgS-wBSRM combines a sliding window mechanism to update the weights of each environmental impact factor, and it can eliminate the impact of the recent service state in the accumulated historical data.

Results: A set of dedicated experiments based on a real world data set and a simulated data set demonstrates that IgS-wBSRM can abandon the expiration information of historical data effectively, and can monitor QoS more accurately.

Conclusions: The overall effect of IgS-wBSRM is better than other QoS monitoring approaches. We suggest directions for follow-up work, e.g., exploring the influence of the size of the sliding window, considering multiple QoS attributes combined with data integration theory and applying IgS-wBSRM in other QoS areas.

1. Introduction

With the emergence of novel techniques, the demand for services between enterprises and individuals transforms into the interactions among different autonomous services. In order to ensure the service adapt to complex and heterogeneous environment, it is critical to monitor Quality of Service (QoS) of third-party web services accurately and sensitively [1–3].

QoS is a set of non-functional attributes of web services. Each QoS attribute, such as *response time* or *reliability*, has a real value [4], and it describes an aspect of web service. Since each quality attribute has a corresponding attribute value, the problem of how to monitor QoS dynamically and sensitively can be transformed into the problem of how to judge QoS attributes effectively and efficiently based on collected QoS data.

In fact, most QoS attributes can be expressed by probability quality property [5]. For example, *response time* can be described as "the probability that the response time of requesting a service is within 10s is more than 90%". *Reliability* can be described as "the probability that monitoring system is off-line within 24 hours should be less than 2%". Consequently, the problem of traditional analysis of QoS attributes is converted into the problem of probabilistic analysis and calculation of collected QoS data in open and uncertainty conditions, which is a recently emerging research area called probabilistic monitoring [6].

Currently researchers have already proposed a number of probability monitoring approaches. Some of these approaches are based on

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simple probability calculation [7]. Others are based on classical hypothesis testing SPRT (Sequential Probability Ratio Test [8]) [6,9,10] or on the Bayesian theory [11,12]. However, most existing probabilistic monitoring approaches are only suitable for traditional software or programs. If these approaches directly apply into QoS monitoring problem, the main issue is that most of these approaches do not consider the influence of different kinds of environment factors [7,9–11], such as *the location of the user*, the *location of the server* and *the load of different time periods*. The influence of these environmental factors in the actual monitoring is extensive and may lead to false monitoring results. We observed and analyzed real-world QoS evaluation dataset from 142 users on 4,532 Web services with 64 different time slots[1]. The data set includes *the user's IP address, server address*, and data for *different time periods*. Consequently, the *response time* with different user's geographical locations and server's geographical locations, and the *response time* of the same service requested of different service locations with different user locations are obtained. As shown in Fig. 1, the horizontal coordinates represent corresponding points of 50 different users' geographical locations and 80 service geographical locations. The vertical coordinate represents the *response time* of the corresponding combinational points (users' geographical locations and service's geographical locations) in the same time periods. Fig. 2 shows the *response time* of the same service requested in the same service's geographical location and same user's geographical location with different time periods. The horizontal represents the different time periods. The vertical coordinate represents the *response time* of the same service request. From Fig. 1 and Fig. 2, it can be concluded that if the QoS monitoring approaches that do not consider the impact of environmental factors may lead to false results. The actual situation does not match the monitor results as the environmental impact factors do affect QoS values. Existing QoS monitoring approaches do not quantify environmental factors, which may lead to wrong monitoring results. In order to solve this problem, our previous work applies TF-IDF algorithm [12] to calculate the impact of environmental factors on QoS monitoring and proposes a novel QoS monitoring approach called wBSRM (weighted Bayesian Runtime Monitoring) based on weighted naïve Bayesian classification. TF-IDF is a widely used weighting technique in information searching and a key technique in measuring relativity between web and searching. TF-IDF algorithm is applied to compute the weight of each environmental factor. However, the approach mainly suffer from the following limitations. *i)* The approach calculates the weights of different environmental factors only according to the initial samples and lacks of updating mechanism. Consequently, it is not suitable in dynamic environments. *ii)* The samples are collected from the beginning until now. In this way, the out-of-date classification information carried by historic and redundant samples may have a negative effect on decision-making, resulting in inaccurate monitoring results. *iii)* When traditional weighting algorithm is used, there is a problem of distribution deviation between decision classification. Due to this problem, changes in the distribution of samples between classes will lead to some abnormal phenomena such as *delay judgment* and *jitter noise*. In order to solve these problems, this paper proposes a novel time-aware monitoring approach, which combines sliding window mechanism and information gain theory [13] to achieve dynamic monitoring of web services QoS, called IgS-wBSRM (Information gain and Sliding window based weighted naïve BayeSian Runtime Monitoring). To support a dynamic mechanism and avoid abnormal phenomena, the approach focuses on time-aware weight of environmental factors by information gain theory. The approach also uses a sliding window mechanism to eliminate the inaccurate monitoring results caused by out-of-date samples.

In summary, the main contributions of this paper are described as follows:

[1] http://www.datatang.com/data/15932.

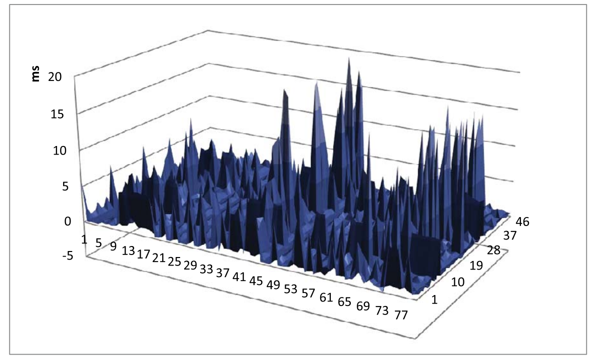

Fig. 1. Response time of the same user location and different server locations at the same time.

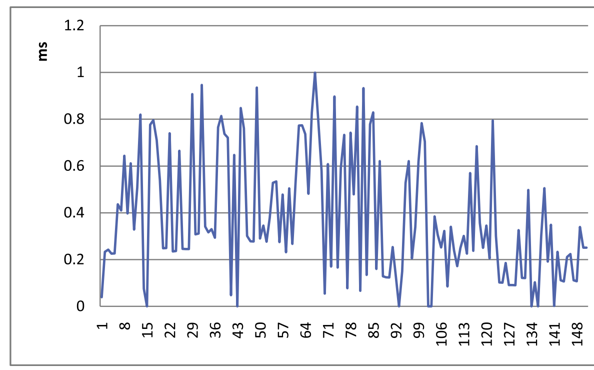

Fig. 2. Response time of the same user location and the same service location in different time periods.

- IgS-wBSRM constructs a fine-grained dynamic monitoring algorithm considering monitoring timeliness. Based on the combination of the sliding window mechanism and the information gain theory, an improved dynamic weight updating algorithm is designed, which is based on the different monitoring sample data sets. This enables the runtime monitoring result always considers the latest sample data and updates the runtime monitoring parameters dynamically.
- Based on a simulation data set under given standard and a real-world data set, a set of dedicated experiments is designed and compared with existing QoS monitoring approaches. The experimental results validate the effectiveness and practicality of IgS-wBSRM.

The rest of this paper is organized as follows: Section 2 introduces the state-of-the-art monitoring approaches for web service QoS and discusses their limitations. Section 3 provides some background materials. The problem analysis, the overview of IgS-wBSRM and the corresponding algorithm are provided in Section 4. In Section 5, we use a simulated data set and a real-world web service QoS data set to validate the proposed approach. Finally, Section 6 gives conclusions and future work.

2. Related work

The related work is divided into two aspects. The traditional QoS monitoring approaches of Web services are surveyed in Section 2.1. Overall, these approaches do not take into account the probabilistic characteristics of QoS. In Section 2.2, the state-of-the-art probability monitoring approaches are described, and existing problems are also analyzed.