Correlated Multi-Dimensional QoS Metrics For Trust Evaluation within Web Services

(Extended Abstract)

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ABSTRACT

Trust and reputation techniques have offered favorable solutions to the web service selection problem. In distributed systems, service consumers identify pools of service providers that offer similar functionalities. Therefore, the selection task is mostly influenced by the non-functional requirements of the consumers captured by a varied number of QoS metrics. In this paper, we present a QoS-aware trust model that leverages the correlation information among various QoS metrics. We compute the trustworthiness of web services based on probability theory by exploiting two statistical distributions, namely, Dirichlet and generalized Dirichlet, which represent the distributions of the outcomes of multi-dimensional correlated QoS metrics. We employ the Dirichlet and generalized Dirichlet when the QoS metrics are positively or negatively correlated, respectively. Experimental results endorse the advantageous capability of our model in capturing the correlation among QoS metrics and estimating the trustworthiness and reputation of service providers.

Categories and Subject Descriptors

H.4 [**Distributed Artificial Intelligence**]: Intelligent agents

General Terms

Design, Theory

Keywords

QoS-based trust, reputation, probabilistic models, generalized Dirichlet

1. INTRODUCTION

The emergence of service-oriented architecture (SOA), the competitiveness of nowadays global markets, and the agility of business processes have contributed to the increase in the number of published web services. Typically, web services are business applications deployed as autonomous and interoperable services. This kind of deployment promises to increase the reachability of the offered services as they are published on the web. It also commits to facilitate the composition of multiple services to provide more functionalities in larger and more complex software applications. However, the web is stocked with service providers that offer similar business functionalities, which leads to service consumers having difficulties in choosing the most appropriate ones. this problem is know in the literature as the web service selection problem. A prominent approach for addressing this problem is incorporated in estimating the trustworthiness of service providers based on the quality of past interactions with them. The service provider with the highest trust score will be then selected to provide the required functionalities.

In this paper, we propose a probabilistic approach to compute the trustworthiness of web services based on multi-dimensional correlated QoS metrics. Therefore, we design a new QoS-aware trust model that leverages the correlations between the observed QoS metrics to estimate the probabilities that the required QoS metrics will yield positive outcomes. This model also provides the uncertainties in these estimates depicted in covariance matrix.

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2. QOS-AWARE TRUST MODEL

The trust model we propose consists of two main modules. The first one allows the agents to select, for each web service they intend to interact with, the QoS metrics they choose to scrutinize. They also specify a threshold under or above which a quality metric is perceived successful. Metrics such as reliability, with values directly proportional to the quality of the service, will be assigned to 1 if they are above the defined threshold and 0 otherwise. The QoS metrics with values indirectly proportional to the overall quality of the service (such as response time) will be assigned to 1 if they are below the define threshold and 0 otherwise. Therefore, these thresholds will be set by the truster agents to meet their non-functional requirements.

In the second module, each web service will be enabled to estimate the expected trustworthiness of potential service providers given the QoS outcomes of their past interactions. Suppose an agent monitors the availability, reliability and response time QoS metrics. After each interaction with a potential service, this agent keeps track of the outcomes of each of the three QoS metrics. Each of the latter is assigned the values 1 or 0 to represent successful or unprofitable outcomes, respectively. After N interactions, the vector $\vec{X} = \{X_a, X_r, X_{rt}\}$ represents the number of interactions for which each of the QoS metrics had successful outcomes. Since $\vec{X}$ is a vector of counts, it is common to assume that it is generated by a multinomial distribution. The Dirichlet distribution is a widely used conjugate prior to the multinomial in various applications including QoS modeling [1]. However, the covariance matrix of Dirichlet is limited by being always negative. Therefore, we apply a generalized Dirichlet (GD) prior instead to estimate the probabilities of each QoS metric to have an outcome equals to 1. The marginal distribution of $\vec{X}$ obtained from the addition of a GD prior to the multinomial is called the multinomial generalized Dirichlet distribution (MGDD).

Therefore, we evaluate the vector of counts of all pairwise combinations of the outcomes of the observed QoS metrics. The size of this vector will be equal to 2^d, where d is the number of QoS metrics. The probabilities of having each of these outcomes combinations are estimated using the first moment of the GD distribution over pairwise joint probabilities. To derive the equation of this moment, let t be the position of the combination outcomes. Since we are dealing with pair-wise combinations of binary values, $t = 1, \ldots, 4$. Therefore, for each of the 11, 10, 01, and 00 outcomes, t is set to 1, 2, 3, and 4, respectively. α_t^{ab} and β_t^{ab} are the parameters of the GD distribution over the pairwise probabilities of the outcomes of QoS metrics a and b. s_t^{ab} be the number of outcomes for which the pair of metrics a and b had the outcome at position t in the vector of outcomes counts. E_t^{ar}, the probability of the outcome of the pair of metrics a and b to be at position t, is given by:

$$E_t^{ar} = \frac{\alpha_t^{ar} + s_t^{ar}}{\alpha_t^{ar} + \beta_t^{ar} + n_t^{ar} + 1} \prod_{k=1}^{t-1} \frac{\beta_k^{ar} + n_{k+1}^{ar}}{\alpha_k^{ar} + \beta_k^{ar} + n_k^{ar}}. \qquad (1)$$

The uncertainties in the above probabilities are denoted by their variances that are given by:

$$V_t^{ar} = E_t^{ar}\Big(\frac{\alpha_t^{ar} + s_t^{ar} + 1}{\alpha_t^{ar} + \beta_t^{ar} + n_t^{ar} + 1} \times \prod_{k=1}^{t-1} \frac{\beta_k^{ar} + n_{k+1}^{ar} + 1}{\alpha_k^{ar} + \beta_k^{ar} + n_k^{ar} + 1} - E_t^{ar}\Big), \qquad (2)$$

and their covariances are defined as follows:

$$C_{tu}^{ar} = E_u^{ar}\Big(\frac{\alpha_t^{ar} + s_t^{ar}}{\alpha_t^{ar} + \beta_t^{ar} + n_t^{ar} + 1} \times \prod_{k=1}^{t-1} \frac{\beta_k^{ar} + n_{k+1}^{ar} + 1}{\alpha_k^{ar} + \beta_k^{ar} + n_k^{ar} + 1} - E_t^{ar}\Big). \qquad (3)$$

Furthermore, we propose a weighted trust function based on the probabilities computed by equation (1). These probabilities are marginalized to obtain $E(P_l)$, the probability of QoS metric l having a successful outcome. The trust scores can be used to assist the selection of agent-based web services by simply suggesting the service provider with the highest score. The proposed trust function is given by:

$$Trust = \sum_{l=1}^{d+1} E(P_l)W_l \qquad (4)$$

where W_l is the weight of the significance of the metric l in the trust computation of the service provider. These weights are defined by the truster agents.

3. EXPERIMENTS

In this section, we compare the accuracy of estimating the correlations among the QoS metrics using the Dirichlet [2] and GD distributions. We consider a QoS vector with two dimensions (two metrics) for which we sample a long sequence of 100,000 outcomes from a multivariate discretized probability distribution with specified correlations. We select 10 sequences of varied length starting at a random positions of the long sequence. For each sequence we compute the mean and covariance estimates, and the correlation between the two metrics using the approach proposed earlier with both Dirichlet and generalized Dirichlet. We report the mean squared errors in the correlation estimations that are averaged over 100 runs. We also compare the accuracy of the correlation estimations using the direct estimation from the outcomes in the examined sequences, and the approach described earlier with both Dirichlet and generalized Dirichlet. Figures 1 and 2 show that GD provides better estimates than Dirichlet in cases of strong and weak positive and strong negative correlations. This is due to the highly flexible covariance matrix of the generalized Dirichlet. Dirichlet estimates weak negative correlations more accurately than GD.

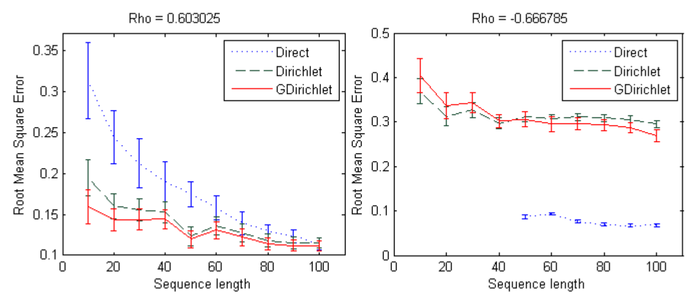

Figure 1: MSE of estimating Strong correlations; positive (left) and negative (right)

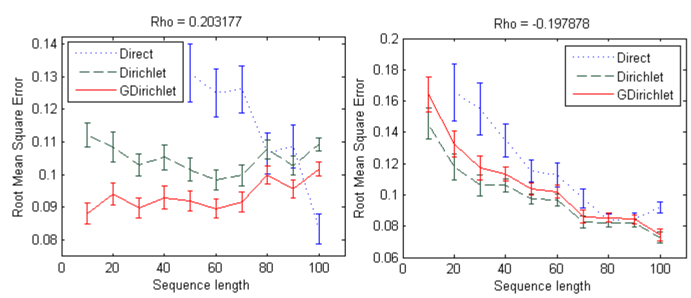

Figure 2: MSE of estimating weak correlations; positive (left) and negative (right)

4. REFERENCES

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