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A Method to Calculate Recommendation Trust of Web Services

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ABSTRACT

Web services are widely accepted and used in the e-commerce. Trust plays an important role in selecting one Web service for application among many services satisfying the demand of requesters and trust for Web services is a hot topic in research fields. This study proposes a method to calculate recommendation trust of Web services and the weight of every recommender is confirmed by norm grey correlation analysis method. The detailed process of the given method is revealed by a specific instance. The method avoids the vicious recommendation and improves the reliability of selected services.

Key words: Web services, recommendation trust, norm grey correlation, weight

INTRODUCTION

Service-oriented Computing (SOC) changed the previous software development. It has been used in e-commerce of cross-organization and within an organization (Liu *et al.*, 2013). Web services are promising in the future. However, there are still some problems to be settled in application of Web services. For example, how to select web services to build secure applications is challenging if many services with the same functions are published by different service providers (Liu *et al.*, 2010).

Recently some trust and reputation approaches have been applied to select web services. Many models for trust and reputation have been studied. Different models use different conceptual frameworks such as simple summation or average of ratings, bayesian systems and belief models. It can be concluded that the trust value generally is involved in initial trust value, direct trust value and recommendation trust value. In this study, recommendation trust of Web services is studied. A new method of the norm gray correlation is used to calculate recommendation trust of Web services.

Trust value data provided by service recommenders are affected by themselves like vicious fake data, whereas the methods about mean value lack the standard of measuring the efficiency of data. These unbelievable data of trust directly affect the accuracy and reliability of data of trust as well as the final result of selecting services. Therefore, they become important to reasonably quantify the weight and the feedback value of service recommenders, effectively avoid the vicious recommendation, calculate the trust data of service recommenders more precisely and improve the accuracy and reliability of selected services.

The weight of indexes can be determined by subjectivity, objectivity or both. The methods for determining the weight of indexes mainly include AHP (Analytic Hierarchy Process)

(Wang and Zhang, 2011), PCA (principal component analysis) (Yan and Zhao, 2006), entropy method (Yao, 2012), neural network method (Jiang, 2007), group grey correlation analysis method (Yan *et al.*, 2008). The grey system theory considers that the essence of indetermination of trust lies in the grey. The grey correlation model based on the grey system theory does not require the excessive number of samples, typical distribution law of samples. The effect of vicious recommendation is weaken. It cannot occur that there is an inconsistency between qualitative analysis and quantitative result as well as the grey correlation. It can get direct quantitative results which can be automatically processed by softwares and be objective to measure the level of trust.

The objective in this study is to compute the weight of each recommender by the norm gray correlation method (Tao *et al.*, 2009) which combines the gray correlation theory and norm. The method overcomes the shortcoming that the previous gray correlation based on the mean may cause the loss of the specific information of correlation factors. It can provide a better approximation than the gray correlation based on average values.

METHOD TO CALCULATE THE WEIGHT OF RECOMMENDERS

The method to determine the weight according to norm grey correlation is based on the grey correlation. It takes full advantage of existing index values. It utilizes the differences between index values and reference values of each evaluated object and obtains the weight taking quantitative differences as cardinality. It is a comprehensive evaluation method to objectively determine weights. Its essence is overall comparison with reference and measurement.

The method is as follows with several steps:

Normalization of index data: Indices can be classified as benefit type, cost type and interval type according to the characteristics of indices. For indices of benefit type, bigger is better. For indices of cost type, smaller means better. For interval type, the closer to some interval $[q_1^j, q_2^j]$ it is, the better, where q_1^j and q_2^j , respectively denote the upper and lower bound of the j -th index value.

Assume there are l objects and n indices, x_{ij} is the j -th index value of i -th evaluation object, z_{ij} is its normalized index value and J_k ($k = 1, 2, 3$), respectively represents benefit type, cost type and interval type index.

$$z_{ij} = \begin{cases} \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} & j \in J_1 \\ \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} & j \in J_2 \end{cases} \quad (1)$$

$$z_{ij} = \begin{cases} 1 - \frac{\max\{q_1^j - x_{ij}, x_{ij} - q_2^j\}}{\max\{q_1^j - \min_i x_{ij}, \max_i x_{ij} - q_2^j\}} & x_{ij} \notin [q_1^j, q_2^j] \\ 1 & x_{ij} \in [q_1^j, q_2^j] \end{cases} \quad (2)$$

Determining a reference sequence x_0 : A reference sequence is determined based on the concrete case. For indices of benefit type, the maximum number is determined as the reference

number. For indices of cost type, the minimum number is determined as the reference number. For indices of interval type, the number 1 is determined as the reference number.

Calculating the absolute values of the difference between each evaluation object and reference sequence: It can be seen that the smaller absolute value is, the closer the distance between the evaluation and its reference sequence. All those differences construct $l \times n$ matrix.

$$\Delta_{ih} = |z_{ih} - x_{0h}| \quad (i = 1, 2, \dots, l; h = 1, 2, \dots, n) \quad (3)$$

Calculating the weight of index: The degree to which sequence j affects other sequence $k (k \neq j)$ in index system is considered. $\gamma_i(j, k)$ denotes the grey correlation coefficient of the i -th point between sequence j and sequence k .

$$\gamma_i(j, k) = \frac{\min_j \min_{g \in I} |y_k(g) - y_j(g)| + \rho \max_j \max_{g \in I} |y_k(g) - y_j(g)|}{|y_k(g) - y_j(g)| + \rho \max_j \max_{g \in I} |y_k(g) - y_j(g)|} \quad (4)$$

$y_k(g)$ and $y_j(g)$, respectively the value of the g -th index of sequence k and j . ρ is distinguishing coefficient. According to the theory of minimum information, in general, $\rho = 0.5$. According to the traditional method of the grey correlation:

$$\gamma_j = \frac{1}{l} \sum_{i=1}^l \gamma_i(j, k)$$

denotes the grey correlation grade sequence j relative to k . It can be seen that the grey correlation grade of some index relative to other index is based on mean value.

The norm grey correlation is introduced as follows.

Let $\eta_i = \gamma_i(j, k)$:

$$\eta^+ = \left\{ \max_k \eta_i = \max_k \gamma_i(j, k) \right\}$$

denotes the ideal sequence of correlation coefficient and

$$\eta^- = \left\{ \min_k \eta_i = \min_k \gamma_i(j, k) \right\} \quad i = 1, 2, \dots, l; k = 1, 2, \dots, n; k \neq j$$

denotes the negative ideal sequence.

η^+ represents the closet sequence relative to reference sequence and η^- represents the farthest sequence. The two norms of the correlation coefficient sequence $y_j (k = 1, 2, \dots, n; k \neq j)$ are defined as follows:

$$d_j^+ = \sqrt{\sum_{g=1}^m (\eta_i(g) - \eta^+(g))^2} \quad (5)$$

$$d_j^- = \sqrt{\sum_{g=1}^m (\eta_i(g) - \eta^-(g))^2} \quad (6)$$

d_j^+ represents the short distance of the sequence j and d_j^- represents the long distance. The smaller the short distance is and the bigger the long distance is, the stronger the relevance of the sequence is. The norm grey correlation grade is defined as follows:

$$\varepsilon_j = \frac{d_j^-}{d_j^+ + d_j^-} \quad (7)$$

$d_j^- = 0$ denotes the weakest correlation sequence and the grey correlation grade $\varepsilon_j = 0$. $d_j^+ = 0$ denotes the strongest correlation sequence and the grey correlation grade $\varepsilon_j = 1$.

The weight of each index is calculated based on the following equation:

$$W = \left\{ w_j = \frac{\varepsilon_j}{\sum_{j=1}^n \varepsilon_j} \mid j = 1, 2, \dots, n \right\} \quad (8)$$

RECOMMENDATION TRUST VALUE OF WEB SERVICES

A service requester submits a requirement. Let $s = \{s_1, s_2, \dots, s_n\}$ be the set of services meeting the requirement and $R = \{r_1, r_2, \dots, r_m\}$ be the set of service recommenders. Each recommender provides the recommendation trust value for each service in the service set satisfying the service requirement. rs_{ij} denotes the recommendation trust value that i -th recommender provides for j -th service. Let $W = \{w_1, w_2, \dots, w_n\}$ be the weight of each recommender. The overall recommendation trust value for service s_j of all recommenders is computed based on the below equation:

$$t_j = \sum_{i=1}^m rs_{ij} w_i \quad (9)$$

Let $(rs_{01}, rs_{02}, \dots, rs_{0n})$ be direct trust value vector for each service in the service set satisfying the requirement given by the service requester. The vector $(rs_{11}, rs_{12}, \dots, rs_{1n})$ represents the recommendation trust vector for each service of i -th recommender.

The trust matrix for (s_1, s_2, \dots, s_n) of the service requester and service recommenders is as follows:

$$T = \begin{bmatrix} rs_{01} & rs_{02} & \cdots & rs_{0n} \\ rs_{11} & rs_{12} & \cdots & rs_{1n} \\ \cdots & \cdots & \cdots & \cdots \\ rs_{m1} & rs_{m2} & \cdots & rs_{mn} \end{bmatrix}$$

T is a $(m+1) \times n$ matrix. According to the grey correlation analysis method, the service requesters are subjects of evaluation and they mostly believe in themselves. Therefore, the vector

$(rs_{01}, rs_{02}, \dots, rs_{0n})$ is treated as the optimal index set. The service requesters synthesize the recommendation for service s_j of all recommenders and obtain the recommendation trust value for service s_j , namely:

$$RT_j = \sum_{i=1}^m rs_{ij} w_i$$

where the weight of each recommender w_i is attained according to the norm correlation method.

Constructing trust matrix: Assume the service requester sends an service requirement and ten services $s = \{s_1, s_2, \dots, s_{10}\}$ satisfying the requirement are found. There are seven service recommenders. The trust matrix is shown in Table 1. The first row denotes the direct trust value for ten services of the service requester. The next seven rows show the direct trust value for ten services of each service recommender.

Calculating the difference values sequence: The absolute values of the difference between each evaluation object and reference sequence are computed based on the Eq. 3. The results are shown in Table 2. Each row denotes the difference of the direct trust value for ten services between service requester and service recommender.

- According to Table 2, it can be concluded that the maximum value M is 0.902055 and the minimum value m is 0.016028 in all $\Delta_i(k)$
- Calculating the correlation coefficient and correlation grade

The correlation coefficient can be gotten by Eq. 4. The results are shown in Table 3. Each row denotes the correlation coefficient between service requester and service recommender:

Determining the ideal sequence and negative ideal sequence: The ideal sequence and the negative ideal sequence of the correlation coefficient of each recommender are listed based on Table 3.

Table 1: Trust value table to services of service requester and service recommenders

Parameters	Service									
	1	2	3	4	5	6	7	8	9	10
Requester	0.941646	0.122982	0.585895	0.935873	0.604079	0.480482	0.806587	0.710893	0.450462	0.123032
Recommender 1	0.967245	0.420957	0.32694	0.262924	0.367968	0.112648	0.901338	0.756553	0.957657	0.374732
Recommender 2	0.145972	0.798978	0.601923	0.594289	0.762884	0.800305	0.484284	0.663156	0.617379	0.05458
Recommender 3	0.441422	0.075037	0.929948	0.033817	0.801844	0.685809	0.325038	0.780759	0.509247	0.472639
Recommender 4	0.488083	0.306669	0.870865	0.114275	0.120322	0.338687	0.609197	0.053713	0.168889	0.688636
Recommender 5	0.747123	0.995961	0.563006	0.142343	0.624725	0.91125	0.318815	0.336332	0.005611	0.337842
Recommender 6	0.245986	0.197538	0.478165	0.326172	0.884311	0.325354	0.562821	0.201298	0.797029	0.004142
Recommender 7	0.231442	0.002636	0.767518	0.817447	0.337382	0.290217	0.358113	0.503094	0.412432	0.515389

Table 2: Difference table between service requester and service recommender

Parameters	Service									
	1	2	3	4	5	6	7	8	9	10
Δ_1	0.025598	0.297974	0.258956	0.672948	0.236111	0.367835	0.09475	0.045659	0.507195	0.2517
Δ_2	0.795675	0.675995	0.016028	0.341584	0.158805	0.319823	0.322303	0.047737	0.166917	0.068452
Δ_3	0.500224	0.047945	0.344053	0.902055	0.197765	0.205327	0.481549	0.069866	0.058784	0.349607
Δ_4	0.453563	0.183687	0.28497	0.821598	0.483757	0.141795	0.19739	0.65718	0.281573	0.565604
Δ_5	0.194524	0.872979	0.02289	0.79353	0.020646	0.430768	0.487772	0.374562	0.444851	0.21481
Δ_6	0.69566	0.074555	0.10773	0.609701	0.280232	0.155128	0.243766	0.509596	0.346566	0.11889
Δ_7	0.710204	0.120346	0.181622	0.118425	0.266697	0.190265	0.448474	0.207799	0.038031	0.392357

Table 3: Correlation coefficient table between service requester and recommender

Parameters (k)	Service									
	1	2	3	4	5	6	7	8	9	10
γ_{01}	0.979921	0.623571	0.65784	0.415539	0.679711	0.570371	0.855761	0.940342	0.487419	0.664633
γ_{02}	0.374633	0.414415	1	0.589262	0.765875	0.605897	0.603954	0.936424	0.755821	0.899083
γ_{03}	0.490991	0.936034	0.587432	0.345179	0.719884	0.71159	0.500823	0.896644	0.916133	0.583357
γ_{04}	0.516317	0.735852	0.634589	0.367002	0.49964	0.78785	0.720301	0.421451	0.637531	0.459415
γ_{05}	0.723499	0.352759	0.985521	0.375279	0.990208	0.529665	0.497503	0.565724	0.521338	0.701456
γ_{06}	0.407308	0.888643	0.835882	0.440316	0.6387	0.770521	0.672222	0.486201	0.585581	0.819514
γ_{07}	0.402207	0.817425	0.738253	0.820183	0.650745	0.728304	0.519238	0.70892	0.95501	0.553787

The ideal sequence is as follows:

$$\eta^+_{0i} = \{0.979921, 1, 0.936034, 0.78785, 0.990208, 0.888643, 0.95501\}; i = 1, 2, \dots, 7$$

The negative ideal sequence is as follows:

$$\eta^-_{0i} = \{0.415539, 0.374633, 0.345179, 0.367002, 0.352759, 0.407308, 0.402207\}; i = 1, 2, \dots, 7$$

Calculating the short distance and the long distance: The short distance is computed by the Eq. 5. The short distance of the sequence of each requester is as follows:

$$\|\eta_{0i}\|_2^+ = \{1.079838, 1.159109, 1.039967, 0.793334, 1.339365, 0.904053, 0.97216\}; i = 1, 2, \dots, 7$$

The long distance is computed by the Eq. 6. The long distance of the sequence of each requester is as follows:

$$\|\eta_{0i}\|_2^- = \{1.025038, 1.197429, 1.189443, 0.796346, 1.091921, 0.938089, 1.031738\}; i = 1, 2, \dots, 7$$

Calculating the norm grey correlation grade: The norm grey correlation grade of each sequence is computed by the Eq. 7. The norm grey correlation grade of each sequence of seven recommenders is gotten as follows:

$$\varepsilon = \{\varepsilon_i\} = \{0.486983, 0.508131, 0.533524, 0.500947, 0.449113, 0.509238, 0.514866\}; i = 1, 2, \dots, 7$$

Calculating the weight of each requester: The above norm grey correlation grades are normalized as the weight of each recommender by the Eq. 8. The result is as follows:

$$w_i = \{0.139027, 0.145064, 0.152313, 0.143013, 0.128215, 0.14538, 0.146987\}; i = 1, 2, \dots, 7$$

Calculating the overall recommendation trust value of each service: The overall recommendation trust value of each service is formulated by the Eq. 9. The result is as follows:

$$RT = \{Rt_j\} = \{0.458257955, 0.386517043, 0.653476616, 0.330080559, 0.559415048, \\ 0.491445652, 0.50753124, 0.474318748, 0.501631622, 0.350162972\}; j = 1, 2, \dots, 10$$

CONCLUSION

More and more concerns are attained by Web services from the industry and the research communities. Nevertheless, some problems need to be solved in use of Web service. One of problems is to select web services to take part in application. With the development of Web services, the number of Web services is increasing dramatically. Many services with the same functions are published by different service providers. This will result in the redundancy of some services with the same functions. When a service requester submits a requirement, there maybe many services meeting the requirement. Trust play an key role in choosing one Web service among many services fulfilling the demands. The recommendation trust is a kind of trust from service recommenders. Recommenders can be some people, applications or agents which once used Web services. Recommenders provide their own trust value to Web service to a service requester. A service requester calculates the overall commendation trust value of Web services based on trust values from all recommenders. The crucial thing is determine the weight of each requester. The norm grey correlation analysis method is used to compute the weight of each requester in this study and a concrete example is used to demonstrate the method. The norm gray correlation overcomes the shortcoming that the previous gray correlation based on the mean may cause the loss of the specific information of correlation factors. It can provide a better approximation than the gray correlation based on average values. It reasonably quantifies the weight and the feedback value of service recommenders, effectively avoids the vicious recommendation and computes the precise trust value of each service improving the accuracy and reliability of selected services.

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