

Capability matchmaking of semantic web services with preconditions and effects

Wang Hai¹ Li Zengzhi¹ Fan Lin²

(¹Institute of Computer System Structure and Networks, Xi'an Jiaotong University, Xi'an 710049, China)

(² Department of Computer Science and Technology, Xi'an University of Post and Telecommunications, Xi'an 710061, China)

Abstract: In order to solve the problem that the current matchmaking methods for semantic web service mainly focus on the matchmaking of IO (inputs, outputs) descriptions which may result in one-sidedness, a description-logic-based IOPE (inputs, outputs, preconditions, effects) description and matchmaking method is proposed for semantic web service. The description logic concept is used to annotate service IO and the description logic assertion is employed to describe service PE (preconditions, effects). TBox subsumption checking is used to measure the subsumption relationship between IO descriptions of service request and advertising; ABox consistency checking is used for checking the logical implication between PE descriptions of service request and advertising. Based upon the logical implication, four kinds of PE matching degrees are proposed to measure and compare the pros and cons of the results of matchmaking. They are the exact, perfect, side-effect and common match. Experiments show that the method has a higher precision rate under the same recall rate compared with the existing method.

Key words: capability matchmaking; semantic web service; precondition and effect

Web services provide a new model of the web in which distributed programs exchange dynamic information on demand. The tools and technology for building and deploying web services are readily available. Automatic service discovery and composition have received much attention because upon these technologies, the automatic business-to-business or enterprise level application integration become possible. Undoubtedly, matchmaking is one of the key techniques to convert these from ideality to reality.

The matchmaking of web services is actually the matchmaking of the service descriptions. Generally, web services matchmaking concerns the matchmaking of the so-called IOPE^[1-2] functional description such as inputs, outputs, preconditions and effects. Intuitively, IO describes the information transformation about the service while PE denotes the state change produced by execution of the service. Previous work concentrates on the matchmaking of IO^[3-8]. These methods use ontology concepts to annotate IO and do the matchmaking by calculating the subsumption or similarity between the IOs in service advertisement and request description. Extending the above IO-based approaches to meet the need of PE is a straightforward consideration. In Ref. [9], the authors proposed a method using logical expres-

sions to describe PE and doing the matchmaking based on the structural equivalence of the expression and also compatibility checking for parameters where the parameters are represented as concepts or individuals in the related ontologies. Similarly, Ref. [10] introduced a method to deal with the PE matching by constructing a mapping between the terms appearing in the PE descriptions of the service advertisement and request. Both of the above two methods are not taken into consideration in the PE matchmaking in a logic-based knowledge representation fashion. Until now, there is still lack of effective methods to solve the matchmaking of PE using logic-based methods. The reason is complex, partly because the techniques to deal with PE are not as mature as needed. In Ref. [11], the authors gave a formalism to describe web services by their PE based on description logic^[12]. The formalism is firmly grounded on the research in the reasoning about action theory.

In this paper, we propose a capability matchmaking method based on the IOPE descriptions. The main contribution of our method is the possibility of using one description logic reasoner to deal with the whole IOPE matchmaking.

1 Formal Description of Services

Although the research of the action community mainly concerns the problem of action reasoning and the reasoning problem is different from the matchmaking problem both in concept and practice level. We also can use the results to solve our matchmaking problem. But the formalism used in service reasoning needs some modification.

We now introduce the formalism for matchmaking about web services. The formalism described below is based on Ref. [2], but the definition of PE is mainly extracted from Ref. [11].

Definition 1 (service) Let T be an acyclic TBox and an atomic ground service $S = (\text{in}, \text{out}, \text{pre}, \text{effect})$.

- A finite set in of SHOIN + (D) concepts, inputs;
- A finite set out of SHOIN + (D) concepts, outputs;
- A finite set pre of SHOIN + (D) axioms, preconditions;
- A finite set effect of SHOIN + (D) axioms, effects.

Definition 2 (preferred interpretations) Let T be an acyclic TBox, $S = (\text{in}, \text{out}, \text{pre}, \text{effect})$ a service for T , and I a model of T . We define the binary relation $\leq_{I, S, T}$ on models of T by setting $I' \leq_{I, S, T} I''$ iff

$$A' \nabla A'' \subseteq A' \nabla A'', \quad s' \nabla s'' \subseteq s' \nabla s''$$

Definition 3 (service application) Let T be an acyclic TBox, $S = (\text{in}, \text{out}, \text{pre}, \text{effect})$ a service for T , and I, I' models of T sharing the same domain and interpretation of all individual names. Then S can transform I to I' iff

- 1) $I \models \text{in}, I' \models \text{out};$

Received 2009-06-30.

Biographies: Wang Hai (1977—), male, graduate; Li Zengzhi (corresponding author), male, professor, lzz@mail.xjtu.edu.cn.

Citation: Wang Hai, Li Zengzhi, Fan Lin. Capability matchmaking of semantic web services with preconditions and effects[J]. Journal of Southeast University (English Edition), 2009, 25(4): 464 – 467.

2) $I \models \text{pre}, I' \models \text{effect}$;

3) There does not exist a model J of T such that $J \models \text{out}, J \models \text{effect}, J \neq I'$ and $J \leq_{I, S, T} I'$.

The above constraints make the results of executing service deterministic, that is, I' is unique by executing the service upon the current world. This formalism does not take into account the changes not caused by executing the service.

2 Matchmaking of Services

For the same acyclic TBox, given two service descriptions $S_r = (\text{in}_r, \text{out}_r, \text{pre}_r, \text{effect}_r)$ and $S_a = (\text{in}_a, \text{out}_a, \text{pre}_a, \text{effect}_a)$, where the S_r represents the requested service and the S_a denotes the advertised usable service. Four principles must be kept in mind to measure the matchmaking:

- Every input needed by S_a can be offered by S_r to some degree;
- Every output requested by S_r should be offered by S_a to some degree;
- The preconditions of S_a must be easier to satisfy than the request, or at least they are as easy to satisfy as each other;
- The effects claimed by S_a must be not less than the request; in other words, the effects expected must be satisfied in the first place.

2.1 Dealing with IO matchmaking

For the situation of IO, we adopt the algorithm proposed in Ref. [5] as a basis. The modification we make to the algorithm lies in the fact that our method does not need S_r having equal numbers of inputs and outputs as well as S_a . So, in our algorithm we do not seek a one-to-one matching between the IO of S_r and S_a . On the other hand, what we expect is that the IO needed by S_a might be offered by S_r .

There exists four degrees of matching for the output:

- 1) Exact match For all the outputs $o_a \in \text{out}_a$, there exists an $o_r \in \text{out}_r$ such that $o_a \equiv o_r$;
- 2) Plug-in match For all the inputs $o_a \in \text{out}_a$, there exists an $o_r \in \text{out}_r$ such that $o_a \supseteq o_r$;
- 3) Subsumes match For all the inputs $o_a \in \text{out}_a$, there exists an $o_r \in \text{out}_r$ such that $o_a \subseteq o_r$;
- 4) Fail match No subsumption relationship is found between outputs of S_a and S_r .

2.2 Situation of PE

The preconditions and the effects with regard to the service description can be regarded as two knowledge base K_{pre} and K_{effect} with respect to the corresponding same acyclic TBox. Accordingly, the matchmaking problem is transformed into a problem of determining the relationship between the two pairs of knowledge bases $(K_{r\text{-pre}}, K_{a\text{-pre}})$ and $(K_{r\text{-effect}}, K_{a\text{-effect}})$. Tab. 1 shows all the possible relationships between the advertisement and the request.

We consider four degrees of matching as described below. Degrees of the described matching below are in a decreasing order of precedence with an exact match having the highest precedence.

- 1) Exact match Obviously, the exact match is number 9, the advertisement is exactly the request;

Tab. 1 All possible relationship

Number	Precondition	Effect
1	$K_{r\text{-pre}} \models K_{a\text{-pre}}$	$K_{r\text{-effect}} \models K_{a\text{-effect}}$
2	$K_{r\text{-pre}} \models K_{a\text{-pre}}$	$K_{a\text{-effect}} \models K_{r\text{-effect}}$
3	$K_{r\text{-pre}} \models K_{a\text{-pre}}$	$K_{r\text{-effect}} \Leftrightarrow K_{a\text{-effect}}$
4	$K_{a\text{-pre}} \models K_{r\text{-pre}}$	$K_{r\text{-effect}} \models K_{a\text{-effect}}$
5	$K_{a\text{-pre}} \models K_{r\text{-pre}}$	$K_{a\text{-effect}} \models K_{r\text{-effect}}$
6	$K_{a\text{-pre}} \models K_{r\text{-pre}}$	$K_{r\text{-effect}} \Leftrightarrow K_{a\text{-effect}}$
7	$K_{a\text{-pre}} \Leftrightarrow K_{r\text{-pre}}$	$K_{r\text{-effect}} \models K_{a\text{-effect}}$
8	$K_{a\text{-pre}} \Leftrightarrow K_{r\text{-pre}}$	$K_{a\text{-effect}} \models K_{r\text{-effect}}$
9	$K_{a\text{-pre}} \Leftrightarrow K_{r\text{-pre}}$	$K_{r\text{-effect}} \Leftrightarrow K_{a\text{-effect}}$
10	No any definite relation	No any definite relation

2) Perfect match In the situation of number 3, effects are matched perfectly and preconditions fulfill $K_{r\text{-pre}} \models K_{a\text{-pre}}$. The semantics of this situation is that the effects advertised are exactly the requested, but the advertised preconditions are easier to satisfy. For example, you searched for a 5 \$ service, but you got a 3 \$ one, cheaper than you expected. Certainly, it is a better choice.

3) Side-effects match Correspondingly, the situation of number 8 means that preconditions are matched perfectly and effects hold $K_{a\text{-effect}} \models K_{r\text{-effect}}$. The semantics of this situation is that if the advertised service is executable then the request service is executable, and vice versa. But by applying the advertised service, we will obtain some additional effects than the requested. The additional effects offered by the advertised service may be good or may be bad. Whatever, we call the excessive part of effects as side-effects. For example, the request is a 5 \$ service to get a hamburger and the advertisement is a 5 \$ service offering a hamburger and also a cup of milk. The additional milk represents the side-effects and this kind of match is called a side-effects match.

4) Common match The last situation we consider is number 2. In this situation, both preconditions and effects are not matched perfectly. The advertised preconditions are easier to satisfy than the requested and the advertised effects are more than the requested. This means that the advertised service can work well as needed, but the requirement of preconditions is much more. Additionally, applying the advertised service will bring side-effects.

3 Proposed Algorithm

Algorithm 1 determines whether a knowledge base entails another. Algorithm 2 is nothing more than a direct depiction of the determination of the different kinds of matching.

Algorithm 1 Bool IsEntail(K_1, K_2)

Transform K_1 to $E(K_1)$

for all $A \in K_2$ do

Transform A to $G(A)$

Add $G(A)$ to $E(K_1)$

if $E(K_1)$ is inconsistent then

delete $G(A)$ from $E(K_1)$

else

return false

end if

```

end for
return true
Algorithm 2 Matchtype IsMatch( $S_r, S_a$ )
 $r_1 \leftarrow \text{IsEntail}(K_{r\text{-pre}}, K_{a\text{-pre}})$ 
if  $r_1 = \text{false}$  then
    return not match
end if
 $r_2 \leftarrow \text{IsEntail}(K_{a\text{-effect}}, K_{r\text{-effect}})$ 
if  $r_2 = \text{false}$  then
    return not match
end if
 $r_3 \leftarrow \text{IsEntail}(K_{a\text{-pre}}, K_{r\text{-pre}})$ 
 $r_4 \leftarrow \text{IsEntail}(K_{r\text{-effect}}, K_{a\text{-effect}})$ 
if  $r_3 = \text{false}$  and  $r_4 = \text{false}$  then
    return common match
else if  $r_3 = \text{true}$  and  $r_4 = \text{true}$  then
    return exact match
else if  $r_3 = \text{false}$  and  $r_4 = \text{false}$  then
    return side-effects match
else if  $r_3 = \text{false}$  and  $r_4 = \text{true}$  then
    return perfect match
end if

```

4 Experiment and Evaluation

In the specification of OWL-S, the preconditions and effects are not described in formalism as we proposed. Directly using the OWL-S service description as input of the matchmaking algorithm will not work. So we prepare the service for experiments by ourselves. We select 100 service descriptions from OWLS-TC^[13] (service retrieval test collection from SemWebCentral) and define the PE descriptions to our formalism. We run both the IO algorithm and the IOPE algorithm for 10 requests and retrieve the ranked result set for each.

For evaluating the matching results, it is common to measure precision at different recall levels. Fig. 1 shows the average precision value at five recall levels. The precision of the IO algorithm is comparatively lower than that of the IOPE algorithm. The reason is not complex. Since without the PE, some IO acceptable results can be regarded as matches. The involvement of PE makes false positive added compared with the barely IO-based matchmaking algorithm.

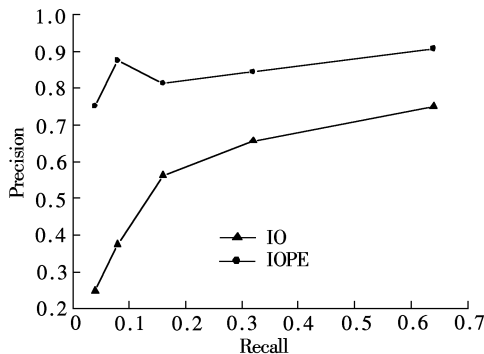


Fig. 1 Precision-recall result

5 Conclusion

We investigate the problem of capability matchmaking with regard to web services, especially the PE matchmak-

ing, and introduce the description logic SHOIN + (D). Then, a formal analysis of web services based on description logic is given, including the formal definition of services and the corresponding semantics behind the definition. According to that definition, we analyze the matchmaking of IO as well as PE. Through the analysis of semantics behind the circumstances, we obtain four kinds of match situations for IO as well as four kinds of match situations for PE. Finally, we study the matchmaking algorithm, especially for PE based on the discussion before. The algorithm is straightforward and practicable. This solution has been examined by our analysis and experiment. It is shown that the solution is suitable for the capability matchmaking about web services.

References

- [1] de Bruijn J, Lausen H, Polleres A, et al. The web service modeling language: an overview[C]//*The 3rd European Semantic Web Conference*. Budva, Montenegro, 2006: 590–604.
- [2] Martin D, Ankolekar A, Burstein M, et al. OWL-S 1.1 release [EB/OL]. (2004-11) [2009-06-10]. <http://www.daml.org/services/owls/1.1/>.
- [3] Bellur U, Kulkarni R. Improved matchmaking algorithm for semantic web services based on bipartite graph matching [C]//*The IEEE International Conference on Web Services*. Salt Lake City, Utah, USA, 2007: 86–93.
- [4] Dragone Luigi. Validation and discovery of non-deterministic semantic e-services[C]//*The 5th International Workshop on Web Services and Formal Methods*. Milan, Italy, 2008: 88–106.
- [5] Li Lei, Horrocks Ian. A software framework for matchmaking based on semantic web technology[C]//*The 12th International Conference on World Wide Web*. New York, NY, USA, 2003: 331–339.
- [6] Payne T R, Paolucci M, Kawamura T, et al. Semantic matching of web services capabilities[C]//*The First International Semantic Web Conference*. Sardinia, Italy, 2002: 333–347.
- [7] Sirin E, Hendler J, Parsia B. Semi-automatic composition of web services using semantic descriptions[C]//*Web Services: Modeling, Architecture and Infrastructure Workshop in ICEIS 2003*. Angers, France, 2003: 17–24.
- [8] Thiagarajan R, Mayer W, Stumptner M. Semantic service discovery by consistency based matchmaking[C]//*The Joint International Conferences on Advances in Data and Web Management*. Suzhou, China, 2009: 492–505.
- [9] Bellur U, Vadodaria H. On extending semantic matchmaking to include preconditions and effects[C]//*IEEE International Conference on Web Services*. Beijing, China, 2008: 120–128.
- [10] Bener A B, Ozadali V, Ilhan E S. Semantic matchmaker with precondition and effect matching using SWRL[J]. *Expert Systems and Applications*, 2009, 36(5): 9371–9377.
- [11] Baader F, Lutz C, Milicic M, et al. A description logic based approach to reasoning about web services[C]//*Workshop on Web Service Semantics: Towards Dynamic Business Integration in WWW'05*. Chiba, Japan, 2005: 636–647.
- [12] Baader F, Calvanese D, McGuinness D, et al. *The description logic handbook: theory, implementation and applications*[M]. Cambridge: Cambridge University Press, 2003.
- [13] Fries B, Khalid M A, Kapahnke P. Owls-tc version 2.2 revision 2 [EB/OL]. (2008-03) [2009-06-10]. <http://www.semwebcentral.org/projects/owls-tc/>.

语义 Web 服务前提与效果功能匹配

王海¹ 李增智¹ 范琳²

(¹ 西安交通大学计算机系统结构与网络研究所, 西安 710049)
(² 西安邮电学院计算机科学与技术系, 西安 710061)

摘要: 为了解决语义 Web 服务匹配方法主要针对服务 IO 描述的匹配, 导致匹配结果较为片面的问题, 提出了一种基于描述逻辑的语义 Web 服务 IOPE 描述及匹配方法. 具体使用描述逻辑概念标注服务 IO, 以描述逻辑断言库刻画服务 PE. 进行服务匹配时, 利用描述逻辑 TBox 概念包含检测确定服务请求与广告 IO 之间的包含关系; 利用描述逻辑 ABox 一致性检测推理, 判断服务请求与广告 PE 之间的逻辑蕴含关系; 依据此蕴含关系, 将 PE 匹配情况划分为 4 种, 即 Exact, Perfect, Side-effect 和 Common 匹配, 用以对匹配结果进行有意义的排序. 实验结果表明, 所提方法在召回率与现有方法相当的情况下, 具有更高的查准率.

关键词: 功能匹配; 语义 Web 服务; 前提与效果

中图分类号: TP311