The Analyzing Method about Behavior Weak Soundness of Web Services based on Open Petri Net

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Abstract: At present, the correctness of the composite Web service is very important. The soundness of the composite Web service model was the core of the correctness of the service composition and can be judged by determining whether or not the composite model satisfied the behavior relativity. But the proposed judging algorithm of behavior relativity was feasible only in the case that T-invariant of Petri net model exists. In the paper, in order to realize the correctness analysis of the composite Web service, an algorithm for determining the behavior weak soundness of the composite service was presented based on the theory of the service tree. The method can analyze the correctness effectively, even if in the case that T-invariant of Petri net model didn’t exist. Finally the concrete example showed the effectiveness of the proposed method.

Key words: Open petri net, weak soundness, web service, behavior relativity, T-invariant

INTRODUCTION

As a new computational resource configuration in the Internet, Web services played a more and more important role in the field of the electronic commerce, enterprise application integration and so on. Many researchers pointed out that services do not only contain static syntax and semantics but also contain some dynamic behavior attributes, e.g., internal control flow, data flow and interact-on protocol (Fu et al., 2004). Now the service composition approach becomes mature, so a large number of large-granularity process web service compositions will occur. These services implied business process a logic and the operations offered have some temporal relation (Fang et al., 2009). Hence, it is key to ensure the correctness after compositions except ensuring the correct function of every service.

At present, the correctness of Web service composition was mainly determined by the soundness and the behavior soundness attracts many researchers’ attentions. Most of these researches were based on Petri Net, finite state machine or automata theory. Based on the concept of service view (Fang et al., 2010) proposed a formal definition of behavior relativity between services, then presented a Petri net method to qualitatively determine and quantitatively compute behavior compatibility (Foster et al., 2004) translated the service composition into the Finite State Machine (FSM) and used labeled transition system analyzer to analyze FSM model, then analyzed behavior compatibility among services by verifying its safety, live and deadlock property (Fu et al., 2004) modeled service composition Business Process Execution Language (BPEL) description by Guarded automata, used temporal logic to describe the goal attribute which is required to meet the interaction process. Then, translated the model into the Promela specification and used Simple Promela Interpreter (SPIN) model checker to verify whether the model meets goal attribute property and it is a high demand for determining the correctness of Web service composition. Martens (2005) applied the workflow net to model Web services and analyze the service behavior compatibility in the composition by verifying safety, live and deadlock property in the Workflow Net. Based on extended the Martin-Lf’s Type Theory (MTT) which supports a type-theoretic formulation of services behavior structured patterns (Yin et al., 2009) proposed the verification on consistency and compatibility of Web services behavior. Fang et al. (2011) studied the soundness property form the language viewpoint of the workflow net system. Net language depiction for soundness was presented to reveal the behavior characteristic of this basic property. Furthermore, synchronous composition and combined composition of the workflow net system was studied. Necessary and sufficient conditions were given for soundness preservation whether the two composition
system. This study provided a novel approach to the modeling and analysis for composition in complex WF-net systems. However, it was difficult to determine the soundness property and it was a high demand for determining the correctness of Web service composition. In the study, though discovering the limitation of the method based on behavior relativity to judge the soundness, a decision method of behavior weak soundness was proposed to determine the correctness of composite Web service.

**BASIC CONCESSION**

A Web service consists of internal structures that realize a local sub process and an interface to communicate with its environment. So modeling services with the help of Open Petri Net, i.e., a Petri Net with an interface. Then, giving out the definition of OPN.

**Definition 1:** A 3-tuple \( N = (P, T, F) \) is called Petri Net (Murata, 1989), where:

- \( P \cup T \neq \phi \)
- \( P \cup T = \phi \)
- \( F \subseteq ((P \times T) \cup (T \times P)) \)
- \( \text{dom}(F) \cup \text{cod}(F) = P \cup T \)
- \( \text{dom}(F) = \{ x \in P \cup T | \exists y \in P \cup T: (x, y) \in F \} \)
- \( \text{cod}(F) = \{ x \in P \cup T | \exists y \in P \cup T: (x, y) \in F \} \)

**Definition 2:** An Open Petri Net is a 7-tuple \( N = (P, I, O, T, F, i, f) \) (Lohmann et al., 2007) where:

- \((P \cup I \cup O, T, F)\) is a Petri net
- \( i \) is a set of input places, \( T \) is a set of transitions; \( F \) is a set of flow relations
- \( t \) is a set of input places and \( \cdot i - \phi \), \( O \) is a set of output places and \( \cdot o = \phi \)
- \( t \) is the initial marking
- \( f \) is the final marking and \( f \) is a deadlock

We call the set \( I \cup O \) the interface places of the OPN. Note that the initial and final markings cannot mark interface places.

As the open Petri net has interface places, termination depends on the communication partners of the net. Still, the aims are to express that at least the service disregarding the communication is modeled in a proper way. Therefore, by considering weak soundness, i.e., soundness without considering the communication which can be seen as generalization of the soundness concept of workflow nets.

**Definition 3:** An OPN \( N \) is called weak sound, if and only if:

- For any marking \( \forall m \in R(N, i_0) \) holds \( s(N) : m \to^{\cdot i} f_i \) i.e., the final marking \( f_i \) is reachable
- For any marking \( \forall m \in R(N, i_0) \), such that \( m \not\preceq f_i \) holds \( m = f_i \)

Two OPNs can by be composed fusing interface places with the same name. Next, we give the condition of two OPNs composed and their composition.

**Definition 4:** Two OPNs \( A \) and \( B \) are composable if and only if they do not share any internal places, input places and output places, i.e., \((P_A \cup P_B \cup O_A \cup T_A) \cap (P_A \cup P_B \cup O_B \cup T_B) = (I_A \cup O_A) \cap (O_B \cup I_B) \) hold (Aalst et al., 2009)

**Definition 5:** Let \( A \) and \( B \) be two OPNs (Aalst et al., 2009). Their composition is an OPN \( A \circ B = (P, I, O, Y, F, i, f) \) defined by:

- \( P = P_A \cup P_B \cup (I_A \cap O_B) \cup (I_B \cap O_A) \)
- \( I = (I_A \cap O_B) \cup (I_B \cap O_A) \)
- \( O = (O_A \cap I_B) \cup (O_B \cap I_A) \)
- \( T = T_A \cup T_B \)
- \( F = F_A \cup F_B \)
- \( i = i_A \cup i_B \)
- \( f = f_A \cup f_B \)

**PROBLEM ANALYZING**

At present, if two Petri nets which are sound have behavior relativity, they will be sound after composition (Van der Aalst et al., 2008). Therefore, the soundness was mainly determined by judging the behavior relativity of the service composition model. Behavior relativity was a good behavior interactive relation. It showed that two components do not change their behavior after interaction and reached the requirement of software composition. Next we give out the decision algorithm for behavior relativity (Fang et al., 2010).

**Algorithm 1:** Behavior relativity decision: \( PN = (P, T, F, M_0) \) is two Petri nets, \( PN = PN_1 \cup PN_2 \), and \( \Delta = T_1 \cap T_2 \). \( X_i \) \((i = 1, 2, ..., q, 1 = 1, 2)\) are all of the minimal T-invariant and \( X_i^{+} = T \cup (-X_i) \) are the non-zero projection vectors of the minimal T-invariant:

- Compute the relational matrices of \( PN_1 \) and \( PN_2 \)
- Compute the T-invariant and the minimal T-invariant of \( PN_1 \) and \( PN_2 \), i.e., \( X_i (j = 1, 2, ..., q, i = 1, 2) \)
Fig. 1: Two different sellers

- Compute the projection vector $X_{ji}^a = \Gamma_{i, a} X_{ji}$, $(j_i = 1, 2, \ldots, q_i, i = 1, 2)$
- Determine whether every vector can be linear represented by the other vectors
- Based on the definition, the decision method is given as follows:
  - If there exists $\exists X_{ji}^a$, $j_i \in \{1, 2, \ldots, q_i\}$ and it can be linear represented by $X_{ji}^a \in \mathbb{R}^{1 \times 2}$, then we call it $\mathfrak{B}(\mathbb{P}_i, \mathfrak{A}(\mathbb{P}_j))$, i.e., they satisfy the consistent behavior relativity

The algorithm need the existence of T-invariant but some Petri net do not have T-invariant. For example, Fig. 1 showed the OPNs of two different sellers. Both sellers do their business in different ways but they are linked together via a common broker-shown in Fig. 2. After Seller 1 has got the order (via channel $c_1$), he waits for the money (channel $m_1$) and send the requested product, afterwards (channel $p$). Seller 2 sends the product immediately after he has received the order. In case he received the money first, he would not send the product at all. Both sellers will terminate their process, if they received the signal to cancel (via channel $c_1$ or $c_2$).

We can compute the relational matrix $A_1$ of the Seller 1 OPN model which is:

$$
A = \begin{pmatrix}
-1 & 1 & 0 & 0 \\
0 & -1 & 1 & 0 \\
0 & 0 & -1 & 1 \\
-1 & 0 & 0 & 1
\end{pmatrix}
$$

Then we compute the T-invariant and we find that the T-invariant do not exist. Therefore, the algorithm cannot be used to determine whether $A_1$ and $A_2$ satisfy the behavior relativity.

Next, we have a research on the case that the T-invariant does not exist.

**THE ANALYZING METHOD ABOUT BEHAVIOR WEAK SOUNDNESS OF WEB SERVICES BASED ON OPEN PETRI NET**

In the study, we use other methods to solve the problem that the T-invariant does not exist. Based on the service tree and its properties, the paper proposes a decision algorithm for weak soundness of Web service
composition. First we introduce some basic concepts of service tree.

**Definition 5:** Let $A_1, \ldots, A_n$ be pairwise composable OPNs (Aalst et al., 2009). Let $c : \{2, \ldots, n\} \to \{1, \ldots, n-1\}$ be such that:

\[
\forall i \in \{2, \ldots, n\}, \ c(i) = i \\
\forall i < j \leq n, \ i = c(j) \Rightarrow I_{A_i} \cap O_{A_j} = \emptyset \Rightarrow \sigma \\
\forall i < j \leq n, \ i \neq c(j) \Rightarrow I_{A_i} \cap O_{A_j} = \emptyset \Rightarrow \sigma
\]

**Definition 6:** Let A and B be two composable OPNs. Condition $\Omega_{A \circ B}$ holds if and only if (Aalst et al., 2009):

\[
\forall m \in R(A \circ B), \sigma \in (T_r)^*: (A : m \xrightarrow{r} f) \\
\Rightarrow (\exists \sigma \in (T_r \cup T_f)^*: (A \circ B : m \xrightarrow{r} f_k + f_r) \\
\land \sigma |_{T_f} = \sigma
\]

Here, $T^*$ is represented as the closure of $T$. $P \xrightarrow{r} f$ is represented as the P reach to f through the transition sequences $\sigma$.

**Theorem 1:** Let $A_1, A_2, \ldots, A_n$ be a service tree with root $A_1$ and tree function $c$. Further, let $A_1$ be weak sound and for $2 \leq i = n, \Omega_{A_1 \circ A_i}$ holds. Then $A_1 \circ A_\ldots \circ A_n$ is weak sound.

Based on the theory, we give the weak soundness decision algorithm.

**Decision Algorithm 2:** Weak soundness.

**Input:** $A_1, \ldots, A_n$ are service components.

**Output:** Decision Result:

1. First, the components are modeled by OPNs. Then, if $A_1, \ldots, A_n$ are pairwise composable, go into
2. Else algorithm terminates
3. If $A_1$ satisfies weak soundness, then continue step (3), else algorithm terminates
4. Determine whether $A_1, \ldots, A_n$ can form service tree, i.e., $c : \{2, \ldots, n\} \to \{1, \ldots, n-1\}$, whether $c$ satisfies the three conditions: $\forall i \in \{2, \ldots, n\}, \ c(i) \neq i$, $\forall 1 < i < j \leq n, \ i = c(j) \Rightarrow I_{A_i} \cap O_{A_j} = \emptyset \Rightarrow \sigma$ and $\forall i < j \leq n, \ i \neq c(j) \Rightarrow I_{A_i} \cap O_{A_j} = \emptyset \Rightarrow \sigma$. If they can, then continue step (4), else algorithm terminates
5. Based on Theorem 1, determine whether when $2 \leq i \leq n$, $A_i \circ A_{i+1} \circ A_{i-1}$ holds. If so, then continue step (5), else algorithm terminates
6. $A_1 \circ A_\ldots \circ A_n$ are weakly sound and algorithm terminates

**EXAMPLE ANALYZING**

In order to verify the validity of our method, we use Fig. 1, 2 to analyze.
CONCLUSION

At present, the correctness of Web service composition is mainly determined by the soundness but the requirement of soundness decision method is high, so the paper researches on behavior weak soundness of Web service composition. Now we mainly determine the soundness by determining the behavior relativity of the service composition model. If two Petri net models are soundness and they satisfy the consistent behavior relativity, then their composite petri net model is also soundness. The method requires the existence of T-invariant but not every Petri net has T-invariant. Therefore, the paper proposes the weak soundness decision algorithm on the basis of service tree and its properties.

Future work mainly contains two aspects: 1) the behavior weak soundness. In the paper, we consider that the interfaces do not affect the process but in the fact, their influences cannot be ignored; 2) the method the paper proposes can only be applied when services satisfy the condition of service tree, hence we need to research more general method to adapt more types of service composition.

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REFERENCES


