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Research Article

The Differential Evolution Method for Constraint Web Service Composition Based on Fuzzy Petri Net

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Abstract: For independent global constraints Web services composition problem, it is difficult to analyze the optimal composition plan. The study presents an optimization method of Web service composition with constraint using Fuzzy Petri Net (FPN) and Differential Evolution (DE), which can transforms solving the optimal service composition problem into locating the largest trust value of legal firing sequences in the FPN model. Then we use the DE algorithm to locate the optimal legal sequences in order to obtain the optimal Web service composition. The experimental results show that the method is effective.

Keywords: Constraint, differential evolution, fuzzy petri net, web service composition

INTRODUCTION

As a new Web application pattern, Service composition has been a popular research. It is defined as the integration of a variety of existing services by certain process logic to satisfy the users' requirements more effectively. The Web service composition approach can be classified into three kinds, including the manual composition, the semi-auto composition and the automatic composition. With the complex of the user requirement, it is difficult to satisfy the user functionality requirement only by single Web service, there should be a possibility to combine existing service components together in order to fulfill the request. This trend has triggered a considerable number of research efforts on the composition of Web services both in academia and in industry (Nalaka and Zahir, 2008).

Locating a composite service would require accurate spe ocating a composite service would require accurate specifications of both service descriptions and user requests. Constraints are used in user requests to accurately describe the services that need to be located. They are of two types: local and global constraints. The former restricts the values of a particular attribute of a single service, whereas the latter simultaneously restricts the values of two or more attributes of multiple constituent services. Global constraints can be classified based on the complexity of solving them (i.e., determining the values that should be assigned to their attributes) as either strictly dependent or independent. A (global) constraint is strictly dependent if the values that should be assigned to all the remaining restricted attributes can be uniquely determined once a value is assigned to one. Services that conform to strictly dependent global constraints can be easily located in polynomial time (Fang *et al*., 2009).

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syntactic-based approaches. But the proposed greedy algorithm approaches are low efficiencies and the approximating method cannot represent some problem accurately. The APN methods (Fang *et al*., 2009) can deal with the constraint modeling but they are deficient in the fuzzy information.

Differential Evolution (DE) algorithm was proposed by Storn and Price (1995), it is a method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. Such methods are commonly known as metaheuristics as they make few or no assumptions about the problem being optimized and can search very large spaces of candidate solutions. However, met heuristics such as DE do not guarantee an optimal solution is ever found. In the furthermore, it was easy to use, with effective and powerful global optimization ability in several areas of success (Ge *et al*., 2009).

So, to solve the Web service composition with independent global constrains, we use Fuzzy Petri Net (FPN) modeling methods to model the component of Web service, in order to describe the constraint relationships, then use the DE optimization methods to locate the legal firing sequences with the biggest trust value in the composite FPN model, for determining the best Web service composition plan.

THE COMPOSITION SERVICE MODELING WITH CONSTRAINT BASED ON FUZZY PETRI NET

Basic conception: The study uses Fuzzy Petri Net (FPN) modeling methods, here; we only introduce several conceptions correlating with the study close, other Petri Nets terms in the literature (Murata, 1989).

Definition 1 (Murata, 1989) (FPN): An 8-tuple FPN = (P, T, D, I, O, f, α, β) is called fuzzy Petri net,

where,

- P = $\{P_1, P_2, ..., P_n\}$ is a finite set of places
- T = $\{T_1, T_2, \ldots, T_n\}$ is a finite set of transitions
- D = $\{d_1, d_2, ..., d_n\}$ is a finite set of propositions
- $|P| = |D|$
- I: $T \rightarrow P^{\infty}$ = An input function, a mapping from transitions to bags of places
- O: $T \rightarrow P^{\infty}$ = An output function, a mapping from transitions to bags of places
- f: T→[0, 1] = The confidence degree of relationship between zero and one
- α: P→[0, 1] = An associated function, a mapping from places to real values between zero and one
- β: P→D = An associated function, an injective mapping from places to propositions

Definition 2 (FPN enabled): In a FPN, a transition may be enabled to fire. A transition t_i is enabled (represented as M [t>) if for all p_j ε $I(t_i)$, α $(p_j) \geq \lambda$ and $c_i \geq \gamma_i$, where λ, γ_i are threshold values and λ, $\gamma_i \in [0, 1]$. A transition t_i fires by removing the tokens from its input places to pass through all support squares and then depositing one token into each of its output places.

The token value in a place p_i, $p_j \in p$, is denoted by $\alpha(p_j)$, where α $(p_j) \in [0, 1]$, If $\alpha(p_j) = y_i$ and β $(p_j) = d_i$, then it indicates that the proposition d_j is y_i.

If the antecedent portion or consequence portion of a Fuzzy Petri Reasoning (FPR) contains "and" or "or" connectors, then it is called a composite FPR. The composite FRP can be distinguished into the following four basic reasoning rule types (Fig. 1). Using this simple mechanism, all the FPRs can be mathematically and graphically illustrated. By carefully connecting related place and assigning reasonable trust values to transitions, we can deal with a FPN that can make a decision based on the expertise during its construction (Murata, 1989).

The basic reasoning rules of FPN: R_i: IF d_f then d_k ($CF = u_i$ here, d_f, d_k are two propositions, the reasoning process is showed in the Fig. 1. In the Fig. 1, the proposition d_f, d_k is represented by the place p_f and p_k respectively, the true degree of proposition d_f is α_f. The dependent relationships of proposition is represented as the transition t_i, its confidence degree is u_i. The composite rules of the propositions are follows:

- **Type 1:** When the transition firing, the true degree of the proposition α_k is $\alpha_f \times u_i$, showed in the Fig. 1a
- **Type 2:** If d_{f1} and d_{f2} and…and d_{fn}, then d_k (CF = u_i) here, d_{fk} $(1 \leq k \leq n) \in D$, the true degree of the proposition d_k is min $(\alpha_{f1}, \alpha_{f2}, \ldots, \alpha_{fn}) \times u_i$, showed in the Fig. 1b
- **Type 3:** If d_f then d_{k1} and d_{k2} and…and d_{kn} (CF = u_i) here, d_{ki} $(1 \leq i \leq n) \in D$, the result is showed in the Fig. 1c
- **Type 4:** If d_{f1} or d_{f2} or…or d_{fn}, then d_k (CF = u_i) here, d_{fk} $(1 \leq k \leq n) \in D$, the result is showed in the Fig. 1d

Definition 3 (composite service): A service tuple CS = $[ws_1, ws_2, \ldots, ws_m]$ is a composite service that conforms to independent global constraints in the FPN model if:

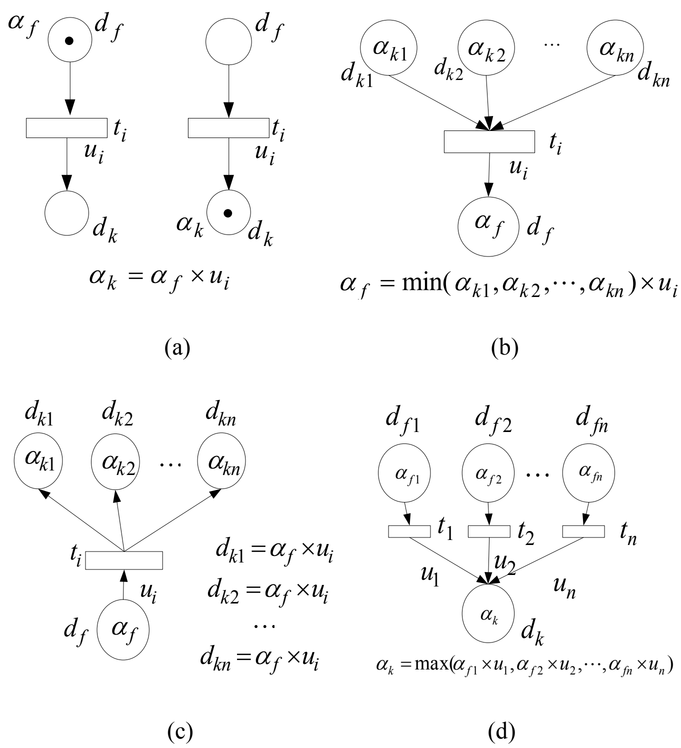

Fig. 1: Four basic type and their reasoning rules

- $\forall w_{si}$, w_{si}, $\in P_{ik}$ ($1 \le i \le m$) here, k is the place number of the i-th level, P_{ik} is the place in the FPN model
- $\forall ws_j$ ($1 \le j \le m-1$) ws_j is described using an attribute a'_i, where $a'_i \in (a_1, \ldots, a_n)$ and ws_{j+1} is described using an attribute a'_{i+1}, where $a'_{i+1} \in (a_1, \ldots, a_n)$
- $\forall ws_j$ ($1 \le j \le m-1$), the trust value $C_{j(j+1)}$ is obtained by the data mining on the basis of the history calling relation between ws_j and ws_{j+1}

Constraint-aware composition service modeling based on FPN: The realization of semi-automatic service composition demands that firstly operators make the universal service composition model in accordance to application demands according to given business background. The model that is usually described by graph includes abstract tasks and dependent relation among tasks. In the model, all task nodes only contain the description of function demands, but do not specify a service instance. Then, select an instance service that meets semantic constraints and the users' requirements from a serial of service class which has the same function attributes for all abstract tasks in the model and finally the composite of service instances can meet the users' requirements (Fang *et al*., 2010).

The composite service acquisition consists of three phases:

- Candidate services acquisition
- Constraint attributes identification
- Optimal composite service acquisition

The first phase locates services with different functions description according to abstract task requirements in a composite service template. A candidate service that satisfies the requirement description of an abstract task is a service with a particular function. By locating candidate services, it ensures that the constituent services of a composite service are of appropriate types. The second phase identifies constraint attributes of services conforming to a given independent global constraint and certain model is used to represent the constraint relations. The proposed methods adopt the transition nodes of FPN to descript the constraint and it is benefit to analyze multi-constraints problem. In the final phase, according to the QoS requirement, the optimal candidate services that satisfy the function and constraint requirement are obtained to form the composite services.

The proposed approach models independent global constraints for composite Web services by the FPN. The place nodes of the FPN model of services composition represent the component services and the transition nodes represent trust value between component services in adjacent process task (Weidlich and Mendling, 2012). The obtaining composite service consists of three phases:

- Candidate services acquisition
- Constraint attributes identification
- Optimal composite service acquisition

The modeling methods about the independent global constraints for composite Web services based on the FPN are presented as follows:

- According to the domain knowledge, a common composite services process model including abstract tasks and the dependent relation between abstract tasks is built by the business personnel, the process model including abstract tasks and the dependent relation between abstract tasks. Each candidate service is represented by a place and the component services satisfying the same abstract task are put the same level.
- The independent global constraints are represented by transitions. If two services have independent global constraints, then the former place is linked with the latter place by directed arc. The confidence factor of transitions is the confidence degree of relationship between places.
- Taking advantage of (1) and (2), a FPN model can be obtained about independent global constraints for composite Web service. The problem of locating instance service is turned into searching the legal firing sequences in the FPN model. Furthermore, the optimal composite services are the legal firing sequences having the largest trust value in the FPN model.

THE OPTIMIZATION OF CONSTRAINT SERVICE COMPOSITION BASED ON DE

By making full use of FPN model, the study uses transition elements of FPN model to encode intimidation population. Concretely, regarding firing sequences of FPN as chromosomes, every legal firing sequence in Petri Net model represent a feasible Web services composition. So the problem of locating instance service is turned into searching the legal firing sequences in the FPN model, then the best firing sequence can be found by optimizing legal sequence with DE. If simply adopting Petri Net to do composite operation, it is very complex when the scale of composition is comparatively large. If DE method is adopted only, searching has comparatively large randomness. It goes against resolving problems effectively (Fan *et al*., 2010). This method takes these two aspects into consideration simultaneously, which reduces the complication and searching randomness effectively.

The optimization methods of independent global constraints for composite service based DE and FPN are as follows:

- **Initialization population:** For a FPN, if it exists a firing sequences $\sigma = t_1 t_2 \ldots t_{n-1}\ t_n$, makes $M_0[\sigma > M_f$, then σ can be regarded as a chromosome, here, M_0 is the first marking, M_f is the end marking, t_1, $t_2 \ldots t_{n-1}$, $t_n \in T$.
  According to the requirement of composite process, we select fixed number (such as M) firing sequences from FPN model with constraints as the first population $x_{\mu 0}$of the DE, here,

  $$x_{\mu 0} = \text{rand}\ [0, 11] \cdot (x_j^{(u)} - x_j^{(L)}) + x_j^{(L)}$$

  $$(i = 1, 2, \ldots, NP;\ j = 1, 3, \ldots, D)$$

- **Mutation operator:** The operation of the mutation operator as follows:

1. Appointing every transition in the firing sequences as a variation point in order
2. For each variation point, replacing it with the new transition in its range according to the mutation probability p_m, then, generating new firing sequences
3. Checking the new firing sequences generating in step 2) by using the legal firing sequences algorithm of Petri net, reserving legal firing sequences, excluding some illegal firing sequences

Though the mutation operator, the mutation vector is as follows:

$$V_{i,G+1} = x_{r1,G} + F \cdot (x_{r2,G} - x_{r3,G})$$

- **Crossover operator:** The operation of the crossover operator as follows:

1. Putting two chromosomes randomly as a group, suppose two chromosome are σ and σ^*, respectively
2. Swapping the same position transition of two firing sequences corresponding chromosome according to the crossover probability p_c, generating some new firing sequences
3. Checking the new firing sequences generating in step 2) by using the legal firing sequences

algorithm of Petri net, reserving legal firing sequences[9], excluding some illegal firing sequences
The test vector is as follows:

$$\mu_{i,G+1} = (\mu_{1i,G+1}, \mu_{2i,G+1}, \ldots, \mu_{Di,G+1})$$

$$\mu_{ji,G+1} = \begin{cases} V_{ji,G+1} & f(rand\ b(j) \le CR) or\ j = rnar(i) \\ x_{ji,G+1} & if(rand\ b(j) > CR) or\ j \ne rnar(i) \end{cases}$$

- **Selection operator:** For decide whether $\mu_{i,G+1}$ will become the next generation members, according to standard, we need compare DE greedy vector with the current population objective vector. If the objective function is too minimized, so it has a small target function value in the next generation of population will win a majority position. The next generation of all individuals is better than the current population of corresponding individual or at least as well.
- **The treatment of boundary conditions:** In the problem of boundary constraints, it is necessary to ensure the new individual values for the parameters in the feasible domain of question; a simple method is to instead randomly the infeasible solution[10]:
  If $\mu_{ji,G+1} < x^{(L)}_j$ or $\mu_{ji,G+1} > x^{(U)}_j$, then $\mu_{ji,G+1} = rand_j (0, 1). (x^{(U)}_j - x^{(L)}_j) + x^{(L)}_j$ (i = 1, 2, …, NP; j = 1, 3, …, D).
- If it does not satisfy terminating condition, then update t←t+1 and consider the first M of the legal firing sequences generating from (7) as the next new group, then go to (4) step. If meeting the terminating conditions, then output results, the algorithm ends.

EXPERIMENT SIMULATION

The methods of independent global constraint service composition based on DE and FPN is proposed, which not only uses FPN superiority in the description multi-attribute multi-constraint problems, but also takes fully Petri net's properties when DE locating in the FPN model into account. In the theoretical, the method is of great benefit to analyze independent global constraint composite service question, which can avoid high complexity using Petri net methods solely and large randomness using DE only.

In order to analyze feasibility and validity of the methods, we compare DE method with FPN method 3 by experiment simulation.

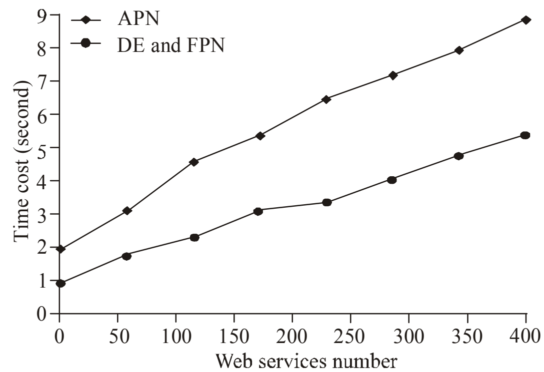

Fig. 2: The execution time of three methods

The experiment is set as follows:

- Building and simulating domain ontology including class, subclass and level relations using Protégé 2000. The concept number of ontology is 50
- Registering a large quantity of services in service library, the service number is 50 to 500
- Setting the function and constraint description of services and mapping input/output and component service parameters to ontology conception
- The number of input/output parameters is 2 to 5; every service includes 3 to 7 component services
- **Experiment environment:** CPU is Intel dual 3.00 GHz, Memory is 2.00 GB and operation system is Windows XP

For a given service requirement, using the DE method, APN method presented in the literature (Fang *et al*., 2009) respectively, the experiment result (Fig. 2) shows the execution time of DE & FPN method is less than the APN method and when the more of the service number in the service library, the better is the effect. The reason is that we uses fully FPN's properties when DE locating in the FPN model, which makes locating space lower and some component services which don't satisfy constraint relations or have minor associate relation need not to match each other. So it can save execution time and improve the time performance of service composition.

In Fig. 3, we locate feasible candidate services from service library and compare the relation graph between the ratio of solution and web services. The experiment result shows the ratio of solution of DE & FPN method is higher than the APN method, but lower than greedy methods. With the web services number adding, the ratio of solution of DE & FPN method decrease quickly.

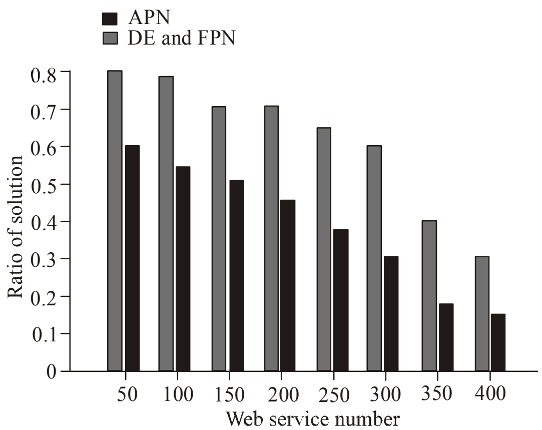

Fig. 3: The ratio of solution and web services

CONCLUSION

To the service composition problem with independent global constraints, the existing research methods are syntactic matching and semantic matching presently. There are greedy methods and approximating methods to deal with global constraints, which play a good effect in resolving constraint problems, but they are deficient to deal with multi-attribute and multi-constraint problems.

The study presents an independent global constrains-aware Web service composition approach based on semantic. Fuzzy Petri Net (FPN) modeling methods are proposed. Then, using the properties and reasoning rules of FPN, a constraint-aware service composition optimization algorithm is presented in order to locate legal firing sequences in FPN model and those corresponding to the legal firing sequences with the biggest trust value are the optimal solutions. When solving a large number of practical optimization problems, we require not only to search the global optimal solution in the feasible region, but also to find more global optimal solutions and meaningful local optimal solutions. To be able to find all the global optimal solution and local optimal solution as much as possible, the study uses DE. Lots of experiments show that this method has both lower time consuming and more optimal solution.

In the future, we should study the behavior constraint service composition methods.

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