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Analyzing Method of Change Region in BPM Based on Module of Petri Net

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Abstract: The change of business modeling is an important problem in Business Process Management (BPM). So, the purpose of the paper is to seek the change region. Especially, the dynamic analyzing method is presented based on module of Petri net. The method can analyze the behaviour of BPM by modular composition and seek the change region. Then, T-invariant is used to optimize the change region in order to get the accurate change region. Finally, given the specific example, it is obvious that the change region obtained by the method is more accurate than the other method. In conclusion, the method of the paper can get the more accurate change region in BPM based on module and T-invariant of Petri net, improving those methods in existing researches and it is effective proved by analyzing the theory and the example.

Key words: Petri net, change region, module, behavioral profile

INTRODUCTION

With constant update of technology of computer, business process has a wide of application and the requirements of people are more and more high. The business process can create many models for different purpose. But not all of these models meet the modeling purpose. They always go wrong in running. Therefore, it is important problem that seeks the change region in Business Process Model (BPM).

Now, many scholars mainly study the consistency between process models. For the analysis of consistency, (Matthias *et al*., 2011a) presented the notion of behavioural profile to measure the consistency of matching activities by analyzing the strict notion of behaviour equivalence. Based on behavioural process, (Matthias *et al*., 2011b) analyzed the types which created the disobedient models and the consistency between process models. Matthias and Jan (2012) analyzed the notion of behavioural consistency and expert perceptions on consistency by comparing the notion of trace equivalence and perceived consistency of experts. On the basis of the above researches, for the analysis of inconsistency, people mainly studied from two aspects: (1) the analysis of behavioural semantics. Gerth *et al*. (2010) established the equivalent standard to seek difference of process models, by comparing the syntax and semantics of process models. Based on semantic similarity, Gao and Zhang (2009) put forward the standard of judging changes.Weidmann *et al*. (2011) presented the way of analyzing the difference of process models based on the synchronous theory of the aligned process model. Based on relevant notions of behavioural profile, Matthias and Jan (2012) defined the behavioural relations of pairs of matching activities and used the fixed change points to seek the change region in process model. (2) The analysis of behavioural process. Fang *et al*. (2012) analyzed the corresponding relation between the source model and the targeted model to fix the change region of the source model, based on the character of dynamic behaviour and the limitation of behaviour. The above researches about the inconsistency of BPM are imperfect. In the view of behavioural semantics, the way of analyzing the inconsistency of process models uses the static analysis and mainly depends on the target model to seek the change region by fixing the observing point. This approach has limitation and inaccuracy and affects the analysis of the consistency between process models.

At the same time, in the view of behavioural process, the way improves the insufficiency of the static analysis in the problem of inconsistency between process models. This approach mainly uses the dynamic analysis and chooses different observing points to seek change region. However, it sill needs to depend on the target model and finding different observing points has blindness. In addition, it affects the accuracy of seeking the change region.

Against this background, in this study, the notion of modular behavioural profile to seek the change region is firstly presented. Then, T-invariant is used to determine the pivotal change route and optimizes the change region for seeking the more accurate change region. Finally, the analysis of an example proves this approach is practical and valid.

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BASIC CONCEPTIONS

This study gives the main notions and other related notions see literature (Fang *et al*., 2009).

Definition 1 (Petri net of business process): A Petri net of business process is a tuple BP = (S, T, F) and it satisfies the following conditions:

- S is the set of condition node and $S \neq \phi$
- T is the set of transition node and $T \neq \phi$
- $S \cap T = \phi$
- $F \subseteq (p \times T) \cup (T \times P)$ is the flow relation of Bp

Definition 2 (T-invariant): Let BP = (S, T, F) is the Petri net of business process, $|S|, = m$, $|T| = n$ and $A_{n \times m}$ is the incidence matrix of BP = (S, T, F). If it exists such a X with the nontrivial n-dimension and nonnegative integer that satisfies $A^T X = 0$, X is called a T-invariant of BP. So, the set of $\|X\| = \{t_i \in T | X(i) > 0\}$ is the set of the pivotal transition.

Definition 3 (Change region): Given the Petri net of business process BP = (S, T, F), If change region is BP = (S, T, F), BP^1 is called a subnet of N, that is $S^1 \in S$, $T^1 \in T$, $BP^1 \subseteq BP$. So, the minimal change region is that there does not exist BP^3 for any $N^2 \subseteq N^1$, holding $|S^3| < |S^2|$, $|T^3| < |T^2|$.

Therefore, change region of BP is the subnet of this net model and its places and transitions in minimal change region are covered by places and transitions in change region.

DETERMINING THE CHANGE REGION BASED ON MODULE

Module: Module was firstly presented by Gallai. It was often applied in the diagram, 2-structure, classification and so on. With the universality of module, many researches begin to decompose the process model by combining module and process model. Modular decomposition can not only clearly analyze the structure of process model, but also is of great benefit to analyzing the relation between pairs of activities. For example, literature (Jan, 2012) abstracts the source process model by using the modular decomposition and constructs its abstract model by analyzing the character of module. This approach avoids the restriction of the target model and can independently analyze the behavioural character of process model. So, to decompose BPM into module can refine the process model and classify according to requirements. Based on the behavioural profile of module, after decomposed the process module, the behavioural relation between modules is analyzed and the commonly output points are observed. Finally, the change region of BPM is fixed.

Definition 4 (Modular decomposition): The strict order relation graph is R = (T, B) of the net BP = (S, T, F).

If $M \neq \phi$, $M \subseteq T$, then $\forall x,y \in M$, $z \in (T/M)$ it holds $(x, z) \in B \Leftrightarrow (y, z) \in B$ and $(z, x) \in B \Leftrightarrow (z, y) \in B$, M is a module. In addition, if there has $M = \phi$ or $M = T$ or $M = \{t\} \in T$, M is a trivial module. And if for any module M, such a module $M_1 \subseteq T$ doesn't exist, holding $M_1 \subseteq M$, M is a simple module. Modular decomposition is a tuple $MG = (\Omega, X)$. Ω is the set of all the simple modules and $X: \Omega \rightarrow \rho(\Omega)$ is a function. To better depict the behavioural relation of process model, the following notion is given:

Definition 5 (Behavioural profile of module): In Petri net of business process BP = (S, T, F), $\forall M, N \in \Omega$ must satisfy one of the following relations:

- The order relation $\Rightarrow$, if $\tau(M, N), = \{\Rightarrow\}$, $\forall x \in M$, $y \in N$, it holds $(x, y) \notin B$ and $(y, x) \notin B$
- The parallel relation $\oplus$, if $\tau(M, N) = \oplus$, $\forall x \in M$, $y \in N$, it holds $(x, y) \notin B$ and $(y, x) \notin B$
- The circular relation $\otimes$, if $\tau(M, N = \otimes)$, $\forall x \in M$, $y \in N$, it holds $(x, y) \in B$ and $(y, x) \in B$

Such that the set of $Mbp = \{\Rightarrow, \oplus, \otimes\}$ is the behavioural profile of module of BP = (S, T, F). And the mapping $\tau: (M_1, M_2) \rightarrow \tau(M_1, M_2)$ is a relational function.

Figure 1 shows the order relation of modules M_1, M_2 and M_3, the parallel relation of modules M_1 and M_2, the circular relation of modules M_4 and M_5.

Seeking the change region of process model based on modular decomposition and T-invariant: Based on the existing researches, this paper firstly decomposes the process module by the analysis method of modular behaviour. Then in order to determine the preliminary change region, the behavioural relation between modules is analyzed by setting different output nodes as observing points. Finally, T-invariant is used to choose the pivotal routes for seeking more accuracy change region. In summary, the following algorithms are given.

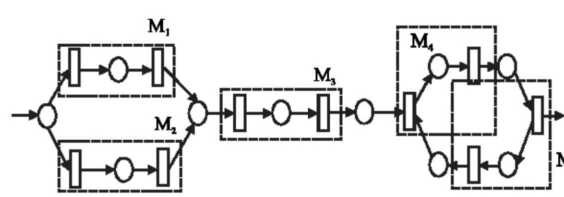

Fig. 1: Behavioural relation of module

Algorithm 1: Seeking the change region based on modular decomposition of Petri net

Input: the Petri net of business process BP = (S, T, F); t_0 is the first transition of BP = (S, T, F), N = |T|; the behavioural profile B_p = {→, +p, $\|_p$}; the strict order relation graph R = T, B; the set Ω; modular behavioural profile MB_p; the set of normal module M_n; the set of change module M_c.

Output: the set of suspected transitions T_0 and change region W.

Step 1: Observing the node t_N, if BP = (S, T, F) can run to t_N, returns to the Step2; otherwise, exits the system

Step 2: Based on definition 4, list all output transitions of Ω in turn: t_1, t_2, t_3, t_4,...,t_{i-1}, t_i

Step 3: In N = (S, T, F), the output transition t_m is set sequentially as the observing point and then list all of modules with setting t_m as the observing point which are not marked. According to definition 5, if $\forall x \in M_1$, $y \in M_2$

- $\tau(M_1, M_2) = \{\Rightarrow\} \in MB_P$, then returns to the Step4, otherwise, returns to Step5
- $\tau(M_1, M_2) = \{\oplus\} \in MB_P$,, then returns to the Step4, otherwise, returns to Step5.
- $\tau(M_1, M_2) = \{\otimes\} \in MB_P$,, then returns to the step (4), otherwise, returns to Step5

Step 4: Puts M_1 and M_2 into M_n and then is numbered sequentially; otherwise, returns to the Step3

Step 5: Puts M_1 and M_2 into M_C and then is numbered sequentially until to the end of the system; otherwise, returns to the Step3

It can get a set of change modules $M_C = \{M_1, M_2,...,M_S\}$, a set of suspected transitions T_0 $M_1 \cup M_2 \cup ... \cup M_S$ and the corresponding change region $W = T_0 \cup \bullet T_0 \cup \bullet T_0 \cup \bullet$

The algorithm 1 uses the advantages of modular composition and the observing points are chose by dynamic analysis. Then the behavioural inconsistency between modules is analyzed. Finally, the change region of business process is initially determined. However, the change region obtained by the algorithm 1 has inaccuracy. In order to reduce change region, the optimal method of change region is given.

Algorithm 2: Optimizing the change region of process model based on T-invariant

Output: The Petri net of business process BP = (S, T, F), the change region W, the set of suspected transitions T_0, the incidence matrix and initial making G = (N, M_0).

Input: optimal change region N_0.

Step 1: Based on definition 2, after solving the formula $A^TX = 0$, gets X and the set of transitions $\|X\| = \{t_iT|X(i)>0\}$

Step 2: Get the region $U = \|X\| U \bullet \|X\| \cup \| \bullet$ by T-invariant

Step 3: Gives all occurring sequences which pass the change region W and the region U: σ_1, σ_2,...,σ_S

Step 4: Get the set of pivotal routes $\sigma = \{\sigma_1, \sigma_2,...,\sigma_S\}$

Step 5: Based on definition 3, taking a sequence σ_i, for any two places s_i and s_j with $s_i \neq s_j$ and i<j in $T_0 \cap \sigma_i$

- If $\bullet s_i \neq \phi$ or $\bullet s_j \neq \phi$, it holds $G_1 = s_i \cup \bullet s_j \cup s_j \cup \bullet \cup ...$, launching forward enabled transitions and places triggered by it, until to the end of the system; otherwise, holds $G1 = \sigma_i$;
- If $\bullet s_i \neq \phi$ or $s^{\bullet}_j \neq \phi$, it holds $G_2 = s_i \cup \bullet s_j \cup s_j \cup \bullet \cup ...$,, launching backward enabled transitions and places triggered by it, until to the end of the system; otherwise, holds $G_2 = \sigma_i$
- Takes down change region $Wi = G_1 \cap G_2 \cap W$

Step 6: Returns to the Step5, selecting the next sequence, until to the end

Step 7: Gives the optimizational change region:

$$N_0 = \bigcup_{i=1}^{m} W_i$$

The algorithm 2 uses T-invariant to filter the pivotal routes for reducing the change region, in order to obtain a more accuracy and optimal change region. This method improves the blindness of existing researches.

ANALYZING EXAMPLE

In actual life, it often comes cross that the result of running BPM is wrong. For example, a customer is shopping online. After completing the transaction, he finds the logistics information is wrong and then he chooses to modify. At the moment, the system requires him to cancel the original order and operate newly. In this operation, it often happens this case: the system prompt the customer doesn't determine the logistic information. Its business process is showed in Fig. 2. After analyzing the system, because of operating delay, the order isn't finished newly.

Because of the behavioural limitation, the business process model can't achieve the expected results. So this paper firstly turns the business process model into the Petri net of business process, as shows in Fig. 3. The algorithm 1 can give the set of suspected transitions T_0 = t_2, t_3, t_4, t_6, t_7, t_8, t_9, t_{10} which is marked with the dashed area in Fig. 3. In the algorithm 2, based on definition 2, it gets the incidence matrix A:

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

So, the vector X = {0, 1, 1, 0, 0, 0, 0, 1, 1, 0, 0, 0} is obtained and the dashed area in Fig. 3 is the change region. Then the pivotal routes are $\boldsymbol{\sigma}_1 = s_2t_2s_3t_4s_4$, $\boldsymbol{\sigma}_1 = s_7t_7s_9t_8s_{10}t_{10}s_{11}$, $\boldsymbol{\sigma}_1 = s_7t_7s_9t_9s_{10}t_{10}s_{11}$. Observing the occurring sequence $\boldsymbol{\sigma}_1 = s_7t_7s_9t_9s_{10}t_{10}s_{11}$ and selecting any two places in the region, it can get $W_1 = G_1 \cap G_2 = \{t_9\}$. Analyzing other occurring sequences, the optimal change region is given which is the shaded area in Fig. 3.

Therefore, it is obvious that filling the order should be put together with the management of logistics information and run together. However, the method of reference "The analysis method about change region of process model based on module" gets the change region

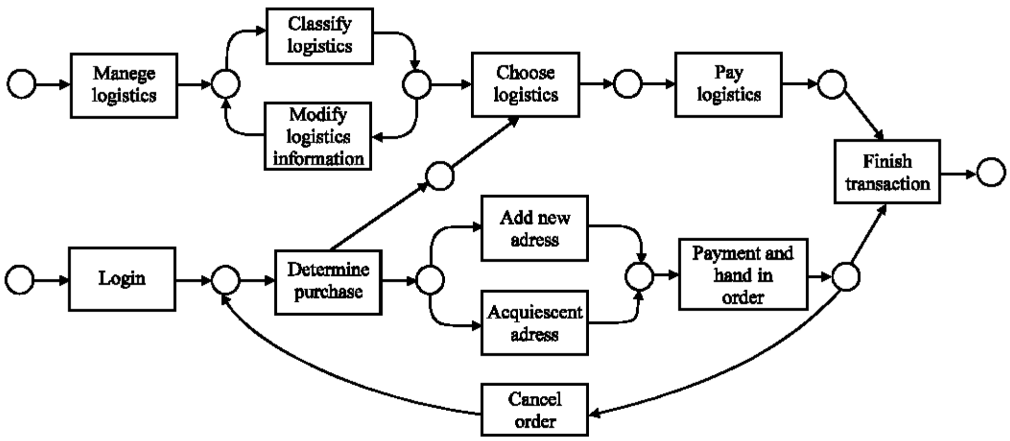

Fig. 2: Business process model of shopping system

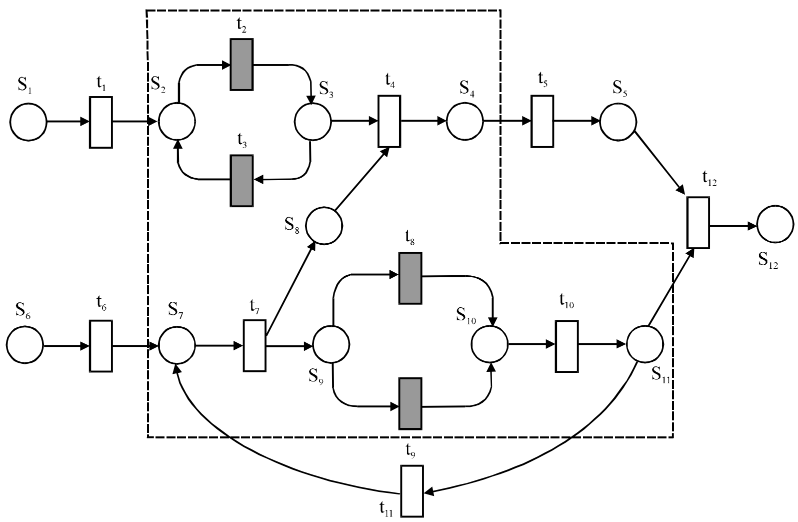

Fig. 3: Change region of the Petri net of business process

$N_0 = \{t_2, t_3, t_4, t_8, t_9\}$. Clearly, the result of this study is more accuracy. So, the method presented by this study is practical and valid.

CONCLUSION

The problems in process models can affect the correctness and feasibility of BPM. So solving the change problem of process models is the main research in business process model management. This paper finds a fast and accurate approach to seek the change region based on the advantages and disadvantages of existing researches and analyzes the behavioural relation between modules based on Petri net and behavioural profile. Especially, T-invariant is used to seek the pivotal routes of change region, in order to obtain the more accuracy change region.

This study firstly uses modules and the dynamic analysis to analyze the behavioural relation of Petri net, avoiding dependence on the target model which causes the inaccuracy in seeking change region. Then T-invariant is used to select the pivotal routes which affect process model, overcoming the blindness of choosing change region. Finally, the determine algorithm the more accuracy change region of business process.

In the future, future work will study the change problem of business process by adding the token. In addition, adjustment and analysis of consistency measure are considered to achieve the requirement of modeling.

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