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An Analysis Method about Change Region of Business Process Model Based On Action Pattern

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Abstract

About the abnormal behavior of business process model, it is the core of work of business process management to determinate the change region which causes abnormal situation. The existing methods of researching change region are based on comparison with source model (or reference model), while it's difficult to obtain source model actually, so these methods are lack of practical operability. In this paper, we construct object sub-model of business process model with labels based on the analysis of behavioral profile of Petri net. A method is proposed to determine change region and the smallest change region based on the concept of action pattern. We evaluate the novel method using a business process model in e-commerce.

Keywords: *Petri net, business process model with label, change region, action pattern*

1. Introduction

Business process model is a method of visualizing the company's process. With the rapid development of computer technology, its applying field is continuing to expand. So it requires the modelers to have promoted in modeling theory and technology to meet different demands of modeling. In practice, business process models based on the same target process can be modeled differently according to different business requirements and various modeling objects. But not all of the models meet the requirements. Thus, it needs to discuss the Consistency between models. Consistency validation is very important in business process modeling. Based on this, it's very important to find out the inconsistent area of models and optimize the model. We can determine the change domain in the process model by looking for inconsistencies region between models. When modeling, it's difficult to obtain the target model, so it has some limitations and be lack of practical utility to determine change region of model by comparing the consistency with source model (or reference model).

Now, there are many scholars in the study of the consistency between process models and looking for the change domain. But all of these are based on the compare of different models. A method was proposed to validate the consistency between a business process model and source model (or reference model) in [1]. The basic concepts of different models were provided in [2], it used the consistency rule to analyze the contact and consistency between different models. The UML2 action Figure software was used in [3] to analyze the compatibility between business process models of different kinds of products; this proposed method can be used to extend the model diversity. The literature [4] also proposed a Provop method to study the business process model diversity; the method can construct the reference model which can be added changes at different levels of abstraction to achieve adaptation. [5]introduced a new concept—behavioral profile to assess the consistency of the behavioral

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relationship between models, he compared behavioral profile and trace equivalence [6-9] to show the advantage of behavioral profile in measuring consistency between models, and specified two types of interference which leads the inconsistency between models. The concept of model similar based on the flow model in language and behavior was defined in [10, 11], it studied the change of model from the side. A synchronization method was proposed based on the consistency of model elements in [12], this method realized the change of the management between business process models in different abstraction levels. [13] explored the propagation of change between allied business process models, used behavioral profiles to research the method of how to narrow the scope of the change region of the allied model in the assumption that the change nodes of process model have been confirmed, but it didn't describe how to determine the change nodes.

Based on the above background, we study the change region of business process model with the absence of resource model (or reference model [14]).

2. Motivating Example

Figure 1 is the Petri net model of shopping online process. The model is verified to be accessible, terminating and with no deadlocks through analyzing the accessibility of this model. The model may be influenced by the internet and other external factors. The result may be different from what we hoped because of the choice to execute when the model is applied. These all may lead to the abnormal situation. The safety of shopping online may be affected and trade disputes may be caused. The reason of abnormal situation is the change domain of the model. It can't be sure whether the change domain of the model exists only through the analysis of the model's accessibility.

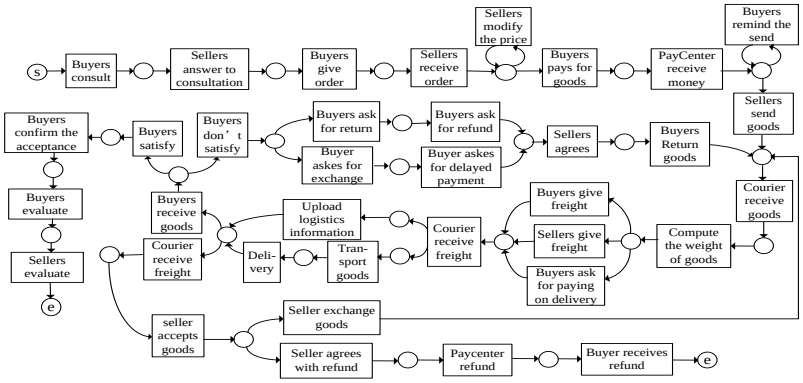

Figure 1. The Petri Net Model of Shopping Online Process

Business process model usually involves multiple service objects. For example, the Petri net model of shopping online process includes three objects: buyer, courier and seller. All activities of service object interweave together according to certain rules and constitute the mainstream of the model. The label of an activity represents the function of the activity. It has closely relation with the behavioral relationship between activities, and has large influence on the behavior of activities. Change region includes change activities and the structural relationship of related activities. The find of change activities is the main step of looking for the change region. It's difficult to find the change region of the model in Figure 1 by using existing methods without source model (or reference model). Thus, it's important to study the method of looking for change domain of model by using the knowledge of including objects

and the labels of activities based on behavioral profile. The analysis method of looking for change region used by action pattern is based on behavioral profile.

3. Basic Concepts

Here we introduce some basic concepts used in this article, and other related concepts can be found in [5, 8].

Definition 1(Process Model Petri Net with Labels) a process model Petri net with labels is a tuple $PM = (P, T, F, C, s, e, l)$ with

(1) P is a finite set of places, T is a finite set of activities, $P = \phi$, $T = \phi$ and $P \cap T = \phi$;

(2) $F \subseteq (P \times T) \cup (T \times P)$ is the flow relation of PM;

(3) $C = \{and, xor, or\}$ is the structural type of PM;

(4) M_o is the initial mark, M_f is the ending mark;

(5) $s \in T$ is the starting activity, $e \in T$ is the ending activity;

(6) $l : T \mapsto \Gamma$ is a mapping assigning to each activity a label, Γ represent the universal alphabet of labels.

There are some related concepts about Petri net, like the input and output set of places and transitions, respectively, marks, firing sequences, accessibility, and so on. These concepts can be found in [8]. If there is a observable execution sequence in the process model Petri net with labels $PM = (P, T, F, s, e, t, l)$, a path from s to e can be found in the PM. It makes sure the model is live, executable, and has no deadlock.

Definition 2(weak order) In a process model Petri net with labels $PM = (P, T, F, s, e, t, l)$, for an arbitrary pair of activity, there is a sequence $\sigma = t_1, \cdots, t_n$, when $i \in \{1, ..., n-1\}$, $i < j \le n$, $t_i = x$ and $t_j = y$, so x, y is in weak order, denoted $x \succ y$.

Definition 3(Behavioral Profile) Let $PM = (P, T, F, C, s, e, l)$ be a process model Petri net, x, y are activity transition nodes, $(x, y) \in T \times T$ is in one of the following relations:

(1)The strict order relation, if $x \succ y$ and $y \not\succ x$, denoted by $x \to y$;

(2)The exclusiveness relation, if $x \not\succ y$ and $y \not\succ x$, denoted by $x + y$;

(3)The interleaving relation, if $x \succ y$ and $y \succ x$, denoted by $x \parallel y$.

The set of all relations is the behavior profile of PM, denoted by $BP_{PM} = \{\to, +, \parallel\}$. Note that we say that a pair of activities $(x, y) \in T \times T$ is in reverse order relation, if $y \succ x$ and $x \not\succ y$, denoted by $x \to^{-1} y$.

4. The Analysis Method of Looking For Change Region Used By Action Pattern Based On Behavioral Profile

This section analyzes how to look for the change region and the smallest change region with the absence of source model (or reference model). The analysis method of looking for change domain used by action pattern based on behavioral profile is proposed. We give the concept of action pattern before introducing our method.

4.1. Action Pattern

Action patterns organize domain specific knowledge in terms of actions and their relations. The term action essentially refers to the verb that describes the work content of an activity. Action pattern capture relations between actions. Action pattern is related to the business semantics of the process model, yet, unlike reference models, action pattern is abstract enough to be reused in various domains.

When constructing business process model, the added labels represent the work of activities in model. To grasp the meaning of activities humans interpret their labels. In the context of this work interpretation of labels has great importance. Hence, we formalize it, introducing a label interpretation function.

Definition 4[9](Action function) For a given process model Petri net with labels $PM = (P, T, F, C, s, e, l)$, the action function $v : \Gamma \mapsto V$ derives an action from a label. As a shorthand notation, we introduce $v_t : \Gamma \mapsto V$ for deriving an action from a label of an activity $t \in T$, i.e. $v(t) = v(l(t))$. We also use $V_{PM} = \cup_{t \in T} \{v(t)\}$ to denote the set of all actions of a process model.

Definition 5(Support and Confidence) For a given process model collection $C = (APM, V)$ and a set of actions $V_0 \subseteq V$, if for $\forall v \in V_0$, there are n PM_i s in C where $v \in V_{PM_i}, i = 1,2,\cdots, |APM|$, we say V_0 has the support of n in C, denoted by $\sup(V_o) = n$.

X、Y are the subset of the set of actions in process model collection $C = (APM, V)$ and $X \cap Y = \phi$, we quantize the dependency of a pair of actions (x, y) by $d(x, y)$, we say X has the confidence of

$$con(X, Y) = \frac{\sum d(x, y)}{|X| \cdot |Y|} \text{ in } Y, \text{where } x \in X, y \in Y.$$

Support set and strength have an important role to explore the behavior relationships between activity transitions in action patterns. They reflect a certain activity transition in the occurrence of an action pattern. Take an example in third section, the seller receives a buyer's order information, he identifies the category of the customer first, then decides the next step behavior. If the support set of action-"receive" information of buyer is 1, the part of service composition as shown in Figure 3 while the support set is 2, as shown in Figure 4.

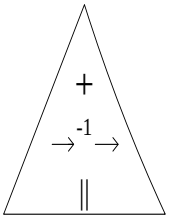

Figure 2.Behavioral relation

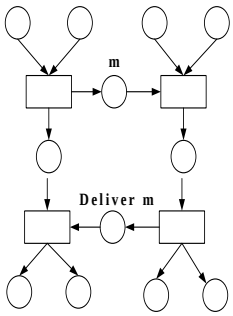

Figure 3. $\sup(re) = 1$

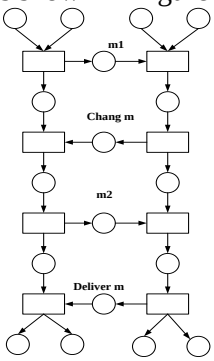

Figure 4. $\sup(re) = 2$ **Hierarchy**

Definition 6(The Value of dependency) In a given process model Petri net with labels $PM = (P, T, F, C, s, e, l)$, for a pair of activities $(x, y) \in T \times T$,the value of dependency $S_{BP}(x, y)$ is defined as following:

(1) If $x \parallel y$, $S_{BP}(x, y)$ =0 ;

(2) If $x \to y$ or $x \to^{-1} y$, $S_{BP}(x, y)$ =1 ;

(3) If $x + y$, $S_{BP}(x, y)$ =2.

Definition 7(Action Pattern based on behavioral profile) For a given process model collection $C = (APM, V)$ and a set of actions $V_0 \subseteq V$, $BPAP = (R, \sup, con)$ is the action pattern based on behavioral profile of C ,where:

(1) $R = X \times Y \in \{\to, \to^{-1}, +, \parallel\}$, $X, Y \subseteq V$ and $X \cap Y = \phi$;

(2) $\sup$ is the support of V_0 in C ;

(3) con is the confidence of X in Y ,where the confidency is defined by $con(X, Y) = \dfrac{\sum S_{BP}(x, y)}{|X| \cdot |Y|}$.

4.2. The analysis method of looking for change region by using action pattern based on behavioral profile

The constructed model may be influenced by the internet or other external factors. The result may be different from what hoped because of the choice to execute when the model is applied. These all lead to abnormal situation. The reason of abnormal situation is the change domain of the model which including change notes and structural dependency of them. The analysis method of looking for the change region (showed in the Algorithm 1) and the smallest change region by using action pattern based on behavioral profile(showed in the Algorithm 2).

Algorithm 1:Looking for the change region of the object sub-models

Input: A process model Petri net with labels $PM = (P, T, F, C, s, e, l)$.

Output: The change region of the object sub-models C_{PM_i} , $i = 1, 2, \cdots, m$, m is the number of the change actions.

(1)Split the given business process model Petri net into there object sub-models according to its including objects PM_1, PM_2, …, PM_n, n is the number of objects.

(2)According to the definition 4, obtain action of every activity in object sub-models. The set of actions in every object sub-models is denoted by V_{PM_i} $i = 1, 2, 3$. Obtain the process model collection $C = (APM, V)$ according to the definition 5, where $|APM| = n$.

(3)Compute the support of v_j according to the definition 3,6 and 8. If $\sup(v_j) \neq 1$, compute the next support. Otherwise, regard v_j as the set's an element of suspected change actions V_S , where $v_j \in V$, $j = 1, 2 \cdots, |V| - 1$. Terminate as $j = |V|$.

(4)According to the definition 3 and 7, compute the confidence of actions in the set of suspected change actions V_S in its own object sub-model. If $con(v_k) \leq 0.5$, compute the next

confidence. Otherwise, v_k is the change action, where $v_k \in V$, $k = 1,2\cdots,|V_s|-1$ .Terminate as $k = |V_s|$.

(5)Get the object change region C_{PM_i} , $i = 1,2,\cdots,m$ by using the change actions and their semantic and structural relation, where m is the number of change actions.

The object change regions C_{PM_i} , $i = 1,2,\cdots,m$ can be obtained through algorithm 1. Then, combing the dynamic characteristics of Petri net, we look for the smallest change region of model by narrowing the scope of object change regions gradually. The algorithm is showed in algorithm 2 as follows.

Algorithm 2: Looking for the smallest change region of business process model

Input: The object change regions C_{PM_i} , $i = 1,2,\cdots,m$, m is the number of change actions.

Output: The smallest change region of business process model.

(1)Get the object change regions C_{PM_i} from algorithm 1, where $i = 1,2,\cdots,m$, m is the number of the change actions.

(2)Get all firing sequences $\sigma_1,\sigma_2,\ldots,\sigma_i,\ldots,\sigma_m$ including the change actions' nodes and going through the object change regions C_{PM_i} , $i = 1,2,\cdots,m$.

(3)Select a sequence σ_i , $i = 1,2,\cdots,m$, choose two different place notes and p_i , p_j with no-repeat, where $i < j$.

(4)If ${}^{\bullet}p_i \neq \phi$ or ${}^{\bullet}p_j \neq \phi$, $S_1 = p_i \cup {}^{\bullet}p_i \cup p_j \cup {}^{\bullet}p_j \cup \ldots$, i.e. the set of all input transition of p_i and p_j , and the set of all input places of transitions and so on; else, $S_1 = \sigma_i$.

(5)If $p_i^{\bullet} \neq \phi$ or $p_j^{\bullet} \neq \phi$, $S_2 = p_i \cup p_i^{\bullet} \cup p_j \cup p_j^{\bullet} \cup \ldots$, i.e. the set of all input transition of p_i and p_j ,and the set of all output places of transitions and so on; else, $S_1 = \sigma_i$.

(6)Get the change region $SC_{PM_i} = S_1 \cap S_2 \cap C_{PM}$ under the sequence.

Return to (3) until all firing sequences are selected. Obtain the smallest change region of business process model $SC_{PM} = \bigcup_{i=1}^{m} SC_{PM_i}$.

5. Case Study

We can use the motivating example in section 2 to verify the validity of our method. Firstly, we construct and split the motivating example into three object sub-models according to the objects of buyer, courier and seller. The buyer object sub-model is presented in Figure 5, the courier object sub-model is presented in Figure 6,and the seller object sub-model is presented in Figure 7.

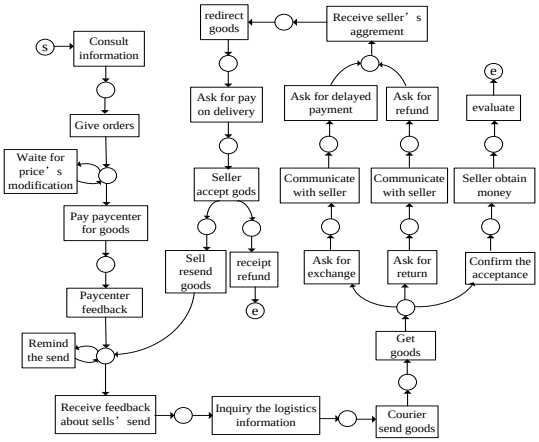

Figure 5. The Buyer Object Sub-Model PM_1

From Table 1, the support of actions in gray shading is 1. These actions form the set of suspicious change actions, denoted by V_S ={transport, pay on delivery, weight, buyer's freight, pack}. {pay on delivery} $\subseteq PM_1$,{pack, transport, weight, buyer's freight} $\subseteq PM_2$. Take the set of including one suspicious change action as X , and the union set of other two sets of actions in object sub-models as Y , we can get the confidence of X in Y . The result is presented in Table 2 as follows.

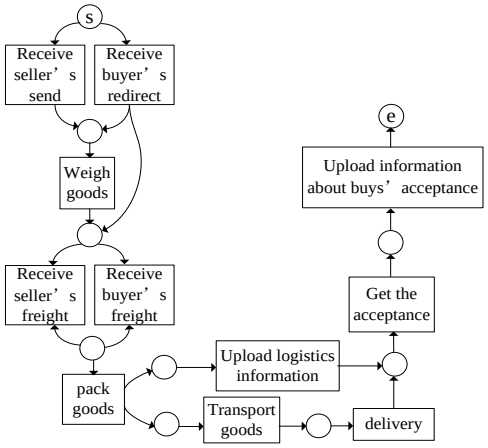

Figure 6. The Courier Object Sub-Model PM_2

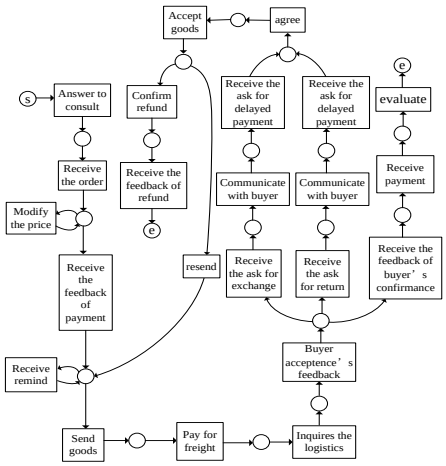

Figure 7. The Seller Object Sub-Model PM_3

Based on the concept of confidence, we can exclude object sub-models' inner actions and find change actions. In Table 2, the confidences of "pay on delivery" and "buyer's freight" are bigger than 0.5, so the corresponded activities of them — " ask for paying on delivery" and "buyer's freight" are change actions in object sub-models. Thus, there are change regions about the freight in model. We find these change regions in gray shading presented in Figure 8.

There are three sequences through the change actions. The change regions under these sequences can be obtained according to algorithm 2. SC_{PM_1} is an empty set, SC_{PM_2} is the region marked 1 in Figure 8, and SC_{PM_3} is the region marked 2 in Figure 8. The smallest change region can be got through algorithm 2.

Table 1. The Support of Actions in V_{PM}

action	support	action	support	action	support	action	support
consult	2	return	2	resend	2	delivery	2
order	2	confirm	2	receipt	2	delay	2
modify	2	Communi -cate	2	weight	1	evaluate	2
pay	2	obtain	2	seller's freight	2	agree	2
pay on delivery	1	seller accept	3	buyer's freight	1	buyer accept	3
remind	2	refund	2	pack	1	feedback	2
logistic	3	send	3	Transport	1	redirect	2
receive	2	get	2	exchange	2		

Table 2. The Confidence of Suspicious Change Actions

suspicious change action	confidence	suspicious change action	confidence	suspicious change action	confidence
pay on delivery	5/8	buyer's freight	10/11	pack	2/11
transmit	2/11	weight	2/11		

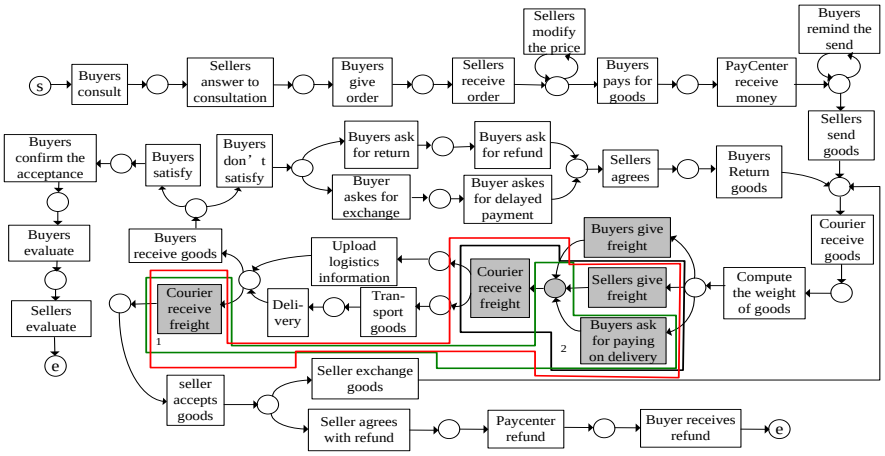

Figure 8. The Change Regions and the Smallest Change Region in Shopping Online Model

6. Conclusions

The existing study about the method of looking for change region is based on the comparison with source model (or reference model). In practice, it's difficult to get source model. Reference model is the general reference of many models in certain domain, it has high abstract level and ignores difference between models constructed according to various business requires. Thus, these existing methods stilly have limitations in looking for change region factually.

The contributions of this paper are embodied in four aspects. Firstly, we construct and split given business process model Petri net into three object sub-models according to its objects. This method overcomes the deficiency with the absence of source model and reference model. Secondly, by introducing the concept of action pattern, the change actions can be found based on the definition of support and confidence. So we can get the change regions of object sub-models through algorithm 1. Thirdly, combining the dynamic characteristics of Petri net, the smallest change region of model can be found through algorithm 2. Finally, we apply our method to solve the abnormal situation of a business process model in e-commerce, the find of the smallest change region verify our method's validity.

We will continue to study the method of how to adapt change region in order to make the model be right based on construction of action pattern.

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