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Analyzing Change Region Model Based on Action Pattern in Business Process Model by Petri Net

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Abstract

About the abnormal behavior of business process model, its one core works 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, some models may be abnormal. Thus, it needs to be discussing the Consistency between models. Consistency validation between models 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 the entire 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]. We may ignore different structure of models can also be consistent with each other by using the concept of process equivalent to judge consistency between models; this method can overcome the defect. 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

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changes at different levels of abstraction to achieve adaptation. The concept of model similar based on the flow model in language and behavior was defined in [5], it studied the change of model from the side. A method was proposed in [6] to detect and resolve differences between business process models with the absence of a change log. It is based on computing differences and deriving change operations for resolving differences. A synchronization method was proposed based on the consistency of model elements in [7], this method realized the change of the management between business process models in different abstraction levels. [8] introduced a new concept - behavioral profile to assess the consistency of the behavioral relationship between models, he compared behavioral profile and trace equivalence [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. [10, 11] studied the concept of consistency and perceived consistency between business process models by launching the network questionnaire survey. [12] 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). At first, we split the model into several object sub-models according to its including objects. The concept of action pattern was introduced to look for the suspected actions which may bring out the change domain of model. The inner activities can be found and removed according to two algorithms we proposed. Combining the knowledge of behavioral profile with semantic and dependent relation of activities, the change region and the smallest change region could be found.

The reminder of this article is structured as follows. Section 2 gives a motivating example. The basic notions are introduced in section 3. We focus on the concept of action pattern, and two important algorithms are given to find the change region and the smallest change region of model in section 4. In section 5, we apply our method to resolve the problems of an example.

2. An motivating example

Fig.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 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.

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 Fig.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 actin pattern is based on behavioral profile.

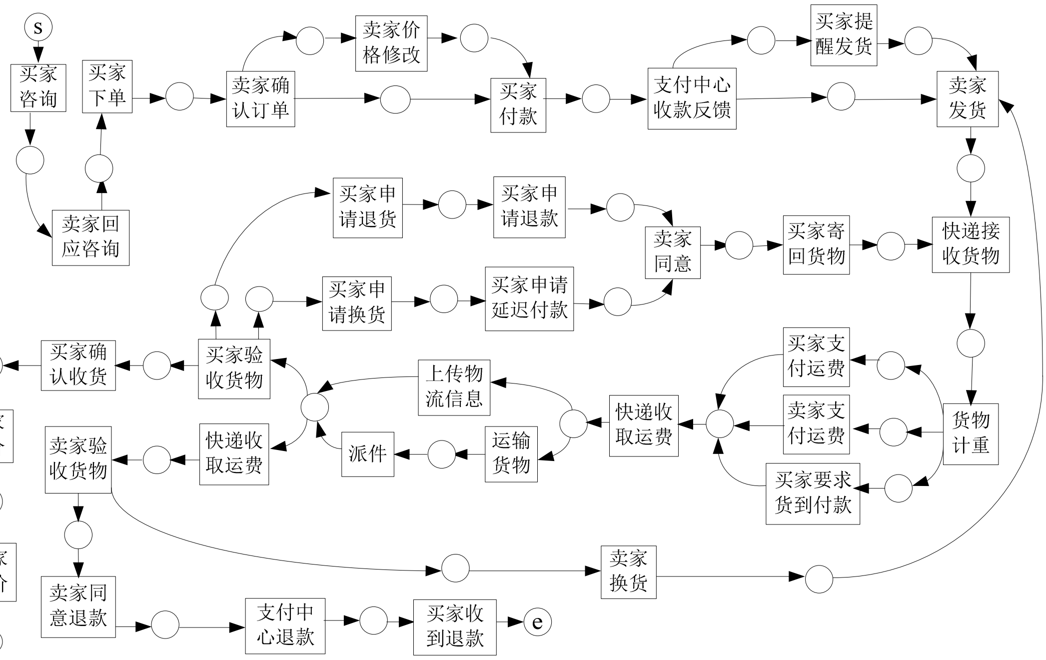

Figure 1. The Petri net model of shopping online process

3. Basic concepts

This part introduces some basic concepts used in this article, and other related concepts can be found in [8, 13]. First, we introduce the notion of a process Petri net with labels used throughout the paper. Then, we define behavioral profile to capture the behavioral characteristics of process model.

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 [13]. 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.

This paper studies the method of searching for change region of model based on behavioral profile. Behavioral profile is established on the basis of weak order, they contains behavioral relations between all activities. In a execution sequence, if an activity happens after another, we say they are in weak order.

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 $y \nsucc x$, denoted by $x \rightarrow y$;

(2)The exclusiveness relation, if $x \nsucc y$ and $y \nsucc x$, denoted by $x + y$;

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

The set of all relations is the behavior profile of PM , denoted by $BP_{PM} = \{\rightarrow, +, \|\}$. 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 $x \nsucc y$, denoted by $x \rightarrow^{-1} y$.

The behavioral profile relations allow different for activities levels of freedom. Interleaving order relation allows the activities to appear in an arbitrary order, (inverse) strict order specifies a particular execution order, and exclusiveness prohibits appearance of two activities in one trace. Thus, we organize the relations into a hierarchy presented in Fig. 2. At the top of the hierarchy the “strictest” relation appears, while at the bottom—the least restrictive.

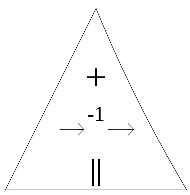

Figure 2. Behavioral relation hierarchy

4. The analysis method of looking for change region used by actin pattern based on behavioral profile

This section topic on 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 actin pattern based on behavioral profile is proposed. We give the concept of actin 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[14](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 $V_{PM} = \bigcup_{t \in T} \{v(t)\}$ to denote the set of all actions of a process model.

Revisiting the motivating example containing the label *buyer consult*, application of the action function v yields the action consult. We also formalize the notion of a process model collection as follows.

Definition 5[14] (Process Model Collection) A tuple $C = (APM, V)$ is a process model collection, where:

– APM is a nonempty finite set of process models with elements $PM_i = (P_i, T_i, F_i, C_i, s_i, e_i, l_i), i = 1, 2, \cdots, |APM|$;

– $V = \bigcup_{i=1,2,\cdots|APM|} V_{PM_i}$ is the set of all actions in the model collection.

Definition 6(Support and Confidence)

(1) 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 $\sup(V_o) = n$.

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

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

(1) R is an association rule between X and Y, $X,Y \subseteq V$ and $X \cap Y = \phi$;

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

(3) con is the confidence of X in Y.

Definition 8(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 $x \| y$, $S_{BP}(x,y)$ =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 9(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:

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

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

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

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 and the smallest change region by using action pattern based on behavioral profile is given as follows.

Firstly, for a given business process model Petri net, we construct and split it into their object sub-models according to its including objects. Then, we compute the support of actions in every sub-model by using the definition of action function. There are four kinds of actions in business process model. The first is the inner actions of object sub-models, the inner actions only appear in its own object sub-models, their support is 1. The second is the actions included in two object sub-models, their support is 2. The third is the actions included in there object sub-models, in a similar way, their support is 3. The last is the change actions, they can be included in one or two object sub-models, never be included in three.

If the change actions exist in one object sub-model, their support is 1 and if they exist in two object sub-models, there are correspondent actions whose support is 1 included in the third object sub-models. Thus, we can regard the actions whose support is 1 as the set of suspected change actions. Lastly, we can exclude the inner actions and find the change actions of object sub-models through our method by used action pattern based on behavioral profile, so we can find the change region of object sub-models by using the knowledge of semantic and structural dependency. The algorithm is showed in algorithm 1.

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's 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 $con(v_k)\geq 0.5$, compute the next's 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 p_i and p_j with no-repeat,where $i < j$.

4. If ${}^{\bullet}p_i \neq \phi$ or ${}^{\bullet}p_j \neq \phi$, $S_1 = p_i \cup {}^{\bullet}p_i \cup p_j \cup {}^{\bullet}p_j \cup \ldots$, e.i.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 $p_j^{\bullet} \neq \phi$, $S_2 = p_i \cup p_i^{\bullet} \cup p_j \cup p_j^{\bullet} \cup \ldots$, e.i.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.

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

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 its including objects of buyer, courier and seller. The buyer object sub-model is presented in Fig.3, the courier object sub-model is presented in Fig.4, and the seller object sub-model is presented in Fig.5.

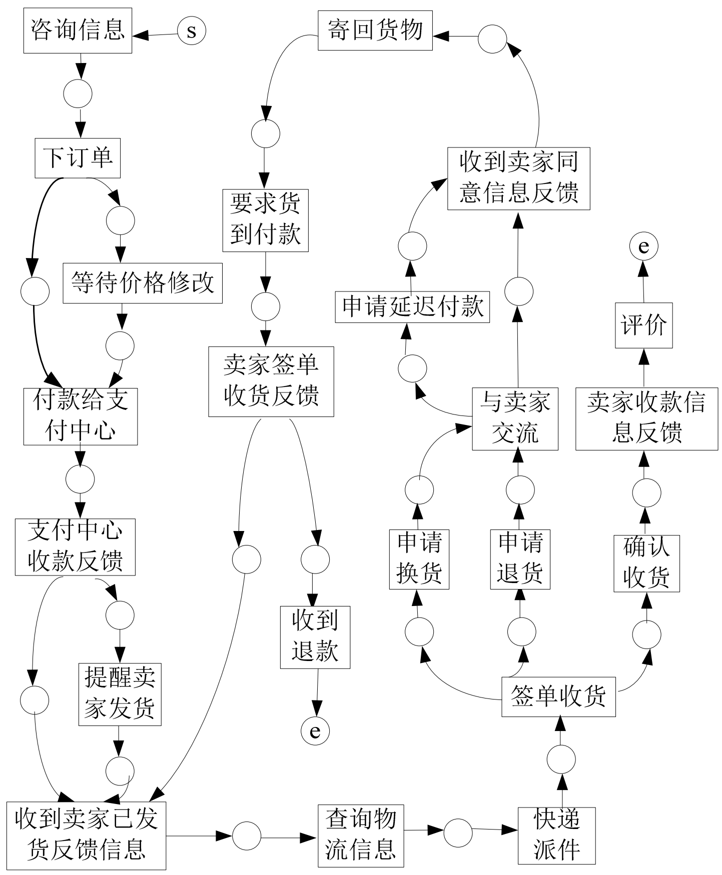

Figure 3. The buyer object sub-model PM_1

According to the definition 4, we can get the set of actions V_{PM_1}={consult, order, modify, pay, feedback, remind, send, logistic,delivery, buyer accept, confirm,receive, evaluate, exchange, delay, return, communicate, agree, back, pay on delivery, seller accept, refund} in PM_1, the set of actions V_{PM_2}={send, back, weigh, seller’s freight, buyer’s freight, logistic, transmit, delivery, buyer accept, seller accept} in PM_2, and the set of actions V_{PM_3}={consult, order, modify, feedback, remind, send, seller’s freight, logistic, buyer accept, pay, evaluate, exchange, return, communicate, delay, agree，seller accept, refund, load} in PM_3. So the set of actions $V_{PM} = V_{PM_1} \cup V_{PM_2} \cup V_{PM_3}$={consult, order, modify, pay, feedback, remind, send, logistic, transmit, delivery, buyer accept, seller accept, confirm, receive, evaluate, exchange, delay, return, communicate, agree, back, pay on delivery, refund, weight, seller’s freight, buyer’s freight, load} in PM. Compute the support of actions in V_{PM}, the result is presented in table 1.

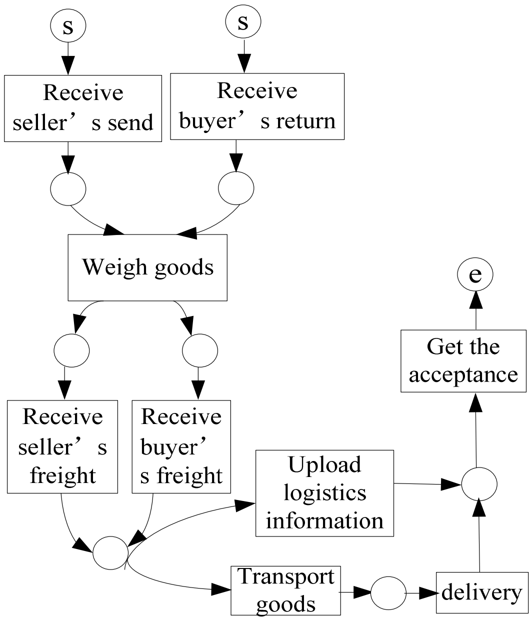

Figure 4. The courier object sub-model PM_2

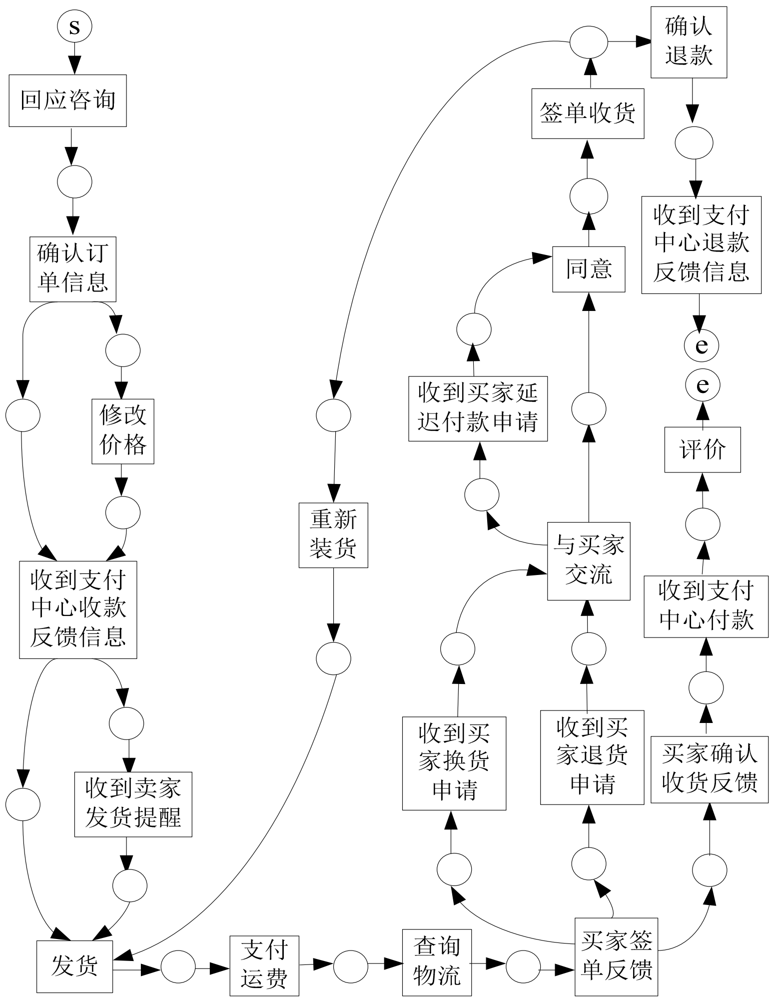

Figure 5. The seller object sub-model PM_3

Table 1. The support of actions in V_{PM}

action	support	action	support	action	support
consult	2	delivery	2	agree	2
order	2	Buyer accept	3	back	2
modify	2	confirm	2	pay on delivery	1
pay	2	receive	2	refund	2
feedback	2	evaluate	2	weight	1
remind	2	exchange	2	seller's freight	2
send	3	delay	2	buyer's freight	1
logistic	3	return	2	seller accept	3
transmit	1	communicate	2	load	2

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 ={transmit, pay on delivery, weight, buyer's freight}. {pay on delivery} $\subseteq PM_1$,{transmit, 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.

Table 2. The confidence of suspicious change actions

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

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. Revisit fig.2, there are three situations when courier get freight of goods. One is that seller gives the freight, another one is that buyer gives the freight, the last one is that buyer asks for paying on delivery. When constructing model, modelers consider that buyer has no responsibility to pay for the freight to exchange or return caused by goods' quality. While, in fact, seller does not accept paying on delivery. Thus, there are change regions about the freight in model. We find these change regions in gray shading presented in fig.6.

They are three sequences through change actions. One is "seller pays for freight—courier receives freight—transmit goods—delivery—upload logistic information—buyer accepts goods", another one is "buyer pays for freight— courier receives freight—transmit goods—delivery—upload logistic information—seller accept goods—seller agrees with return—paycenter refund—buyer receives refund", the last one is “buyer ask for paying on delivery-courier receives freight—transmit goods—delivery-upload logistic information—seller accept goods—seller agrees with return —paycenter refund—buyer receives refund”. The change regions under these three sequences can be obtained according to algorithm 2. SC_{PM_1} is an empty set, SC_{PM_2} is the region marked 1 in fig.6, and SC_{PM_3} is the region marked 2 in fig.6. The smallest change region can be got through algorithm 2. It is the region surrounded by red line in fig.6

6. Conclusion

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 including 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 an 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 to make the model be right based on construction of object sun-models and the notion of action pattern.

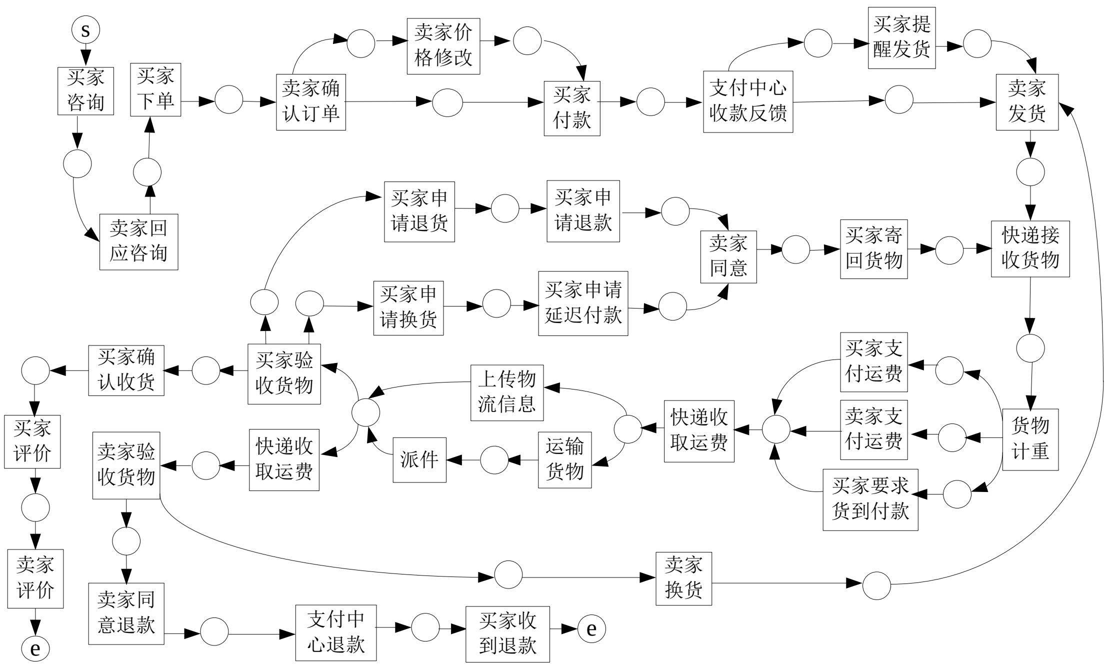

Figure 6. The change regions and the smallest change region in shopping online model

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