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Change impact analysis for service based business processes

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Change Impact Analysis for Service Based Business Processes

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Abstract—Change management is critical and challenging in the development and maintenance of service-based applications and information systems due to the distributed and dynamic nature of services. This paper proposes an approach for facilitating the change impact analysis in a service oriented environment. This research focuses on a typical scenario that multiple services are supported by a single business process. The change impact is analyzed based on the study of the dependency between services and business processes. Types of changes and change impact patterns are identified on the foundation of a service oriented business process model. These change types and the impact patterns can be used to enable the analysis of change propagation of the business process and associated services. Algorithms for computing impact scopes of changes are provided.

Keywords-service oriented computing; web service; change management; service evolution; business process

I. INTRODUCTION

Change management is a challenging issue in the service oriented environment due to the distributed and dynamic characteristics of services [1]. In the service oriented computing (SOC) paradigm, business processes and services are coupled with each other when services expose business functions of business processes [2]. Due to various reasons such as business regulations and application environments, services and business processes may change from time to time. A specific service change usually affect the associated business processes and services and a change occurred in a business process often causes various levels of impact on the associated services.

Let us consider a purchase scenario as an example. A purchase process receives an order from a buyer, checks the stock availability, and sends confirmation to the buyer. If an order has been received, the purchase process sends the bill to the buyer. The payment is processed by a finance institute. The buyer is issued with an invoice after the payment. The purchase process handles the shipment of the goods with the support of a shipping company. In this scenario, the purchase process interacts with three partners as a buyer, a finance institute, and a shipping company. In the SOC environment, these three partners take part in the purchase process by invoking the corresponding services exposed by the purchase process. Each service is an external view of the purchase process from a specific partner. Private tasks of the purchase process, such as checking stock availability and processing an invoice are hidden from its partners.

The above scenario exemplifies a typical case of the coupling relation between services and business processes when multiple services are supported by a single business process. If a change occurs in any of the services, it will definitely affect the business process and may have impact on the other services associated with this business process. If a change occurs in the business process, the change may affect the services that are associated with this business process. For supporting the change management, it is necessary to identify different types of changes and change impact patterns and have effective mechanisms to deal with them.

Current researches about service change management are mainly concentrated on managing changes for BPEL processes [3], [4] and Web services [5], [6], [7] respectively. The complex dependencies between services and business processes are neglected by the existing works when dealing with changes for service-based applications and information systems. As the first step to study on these dependencies, the research focuses on the change impact analysis in service oriented context and highlights one of typical cases that multiple services are supported by a single business process.

The goal of this research is to manage the various types of changes associated with services and business processes by developing effective mechanisms for controlling changes and minimizing their impact on other services and business processes. The proposed approach is based on the service oriented business process model which captures a typical type of dependency between services and business processes. A number of change impact patterns are specified on the basis of the identified various types of service changes and business process changes. The change propagation within service based business processes can be analysed with the help of these identified change impact patterns.

This research specifies change impact patterns based on the proposed service oriented business process model and the various types of changes of services and business processes. Each change impact pattern provides an understanding of the direct impact scope of a change, the cause of the change, the effect of the change on the services and the associated business process. The change impact patterns
provide intermediate results in the analysis process and they can be reused in the development and maintenance of service based information systems. This paper also provides how to analyse the change propagation of services and business processes with the support of the change taxonomy and the change impact patterns. The algorithms are defined to calculate the impact scope of a specific change.

The remainder of this paper is structured as follows. Section 2 describes the service oriented business process model. In Section 3, the identified change types relating to services and business processes are presented. Based on these change types, Section 4 presents the ten change impact patterns and the functions for calculating direct impact scopes of a service change and a process change. Section 5 discusses the change propagation and the actual impact scopes of a service change and a process change. Section 6 reviews the related work. Section 7 concludes the paper.

II. SERVICE ORIENTED BUSINESS PROCESS MODEL

This section presents the service oriented business process model. The proposed model contains two layers as a process layer and a service layer. The two layers and their relations will be described as follows.

A. Process Layer

The process layer contains internal processes. An internal process consists of a control flow schema and an information flow schema.

Control Flow Schema

The control flow schema consists of a set of activities and the control relations associated with them. Activities are categorized into private activities (p-activities) and communication activities (c-activities) [8], [9]. P-activities are invisible to partners. C-activities exchange information with partners. C-activities are further categorized into four types: receive, send, receive/reply, invoke/receive.

Definition 1 (Control flow schema) The control flow schema of an internal process is defined as a 3-tuple: $\text{CFS} = (A, C, E)$, where:
- $A = \{a_1, \ldots, a_n\}$ is a set of activities. For $a \in A$, if $a$ is a c-activity, a partner denotes the partner that $a$ intends to interact with;
- $C = \{\oplus \text{split}, \oplus \text{join}, \odot \text{split}, \odot \text{join}\}$ is the set of control connectors, where $\odot$ represents the and connector while $\oplus$ denotes the xor connector;
- $E = \{e_1, \ldots, e_m\}$ is a set of directed edges associated activities and connectors.

Figure 1(a) shows the control flow schema of a purchase process which intends to interact with two partners: a buyer and an financial institute.

Information Flow Schema

The information flow schema defines how data is transferred between activities. The information flow is the key for understanding the data dependency between activities which is indispensable for analyzing change impact. We define the information flow schema which is similar to the data flow schema defined in [10].

Let $D = \{d_1, \ldots, d_n\}$ be a set of data elements associated with the internal process. Every activity $a$ has input and output parameters, denoting as InPARs$(a)$ and OutPARs$(a)$ parameters respectively. A data connection is defined as $dc = (d, a, \text{par}, \text{mode})$ where $d \in D$, $a \in A$, par $\in \text{InPARs}(a) \cup \text{OutPARs}(a)$, and $\text{mode} \in \{\text{read}, \text{write}\}$.

Definition 2 (Information flow schema) Let $\text{CLF} = (A, C, E)$ be the control flow schema of an internal process, the information flow schema is the set of all data connections $\text{IFS} = \{dc_1, \ldots, dc_m\}$.

Figure 1(a) shows the part of the information flow schema of the purchase process. The dashed arrows are the data connections. After receiving the order from a buyer, the activity receive order writes $d_1$ with the information: customer order. The data connection is $(d_1, \text{receive order}, \text{customer order}, \text{write})$. Then send acknowledgement reads from $d_1$ as input parameter and sends an acknowledgement to the buyer. The data connection is $(d_1, \text{send acknowledgement}, \text{customer order}, \text{read})$. Data dependency between activities is derived from data connections. There is a data dependency between receive order and send acknowledgement as the input of the latter is retrieved from the output of the former. We say receive order depends on send acknowledgement in terms of data.
Definition 3 (Activity data dependency) Let $CLS = (A, C, E)$ be the control flow schema of an internal process, $IFS = \{dc_1, \ldots, dc_m\}$ be the information flow schema, and $D = \{d_1, \ldots, d_n\}$ be the set of data elements associated with the internal process. For $a_i, a_j \in A$, $a_j$ depends on $a_i$ in terms of data, denoting as $a_i \rightarrow_D a_j$ iff: (1) $\exists dc_x, dc_y \in IFS$ such that $dc_x = (d, a_j, par_x, \text{write})$, $dc_y = (d, a_i, par_x, \text{read})$, where $d \in D$, $par_x \in \text{OutPARs}(a_j)$ and $par_x \in \text{InPARs}(a_i)$, and (2) $a_j$ precedes $a_i$ in $CLS$.

To sum up, an internal process is defined by a 2-tuple: $IP = (CLS, IFS)$, where $CLS$ is the control flow schema while $IFS$ is the information flow schema.

B. Service Layer

The service layer contains services supported by an internal process. Every service is an external view of the internal process from the view point of a partner. Observable behavior rather than a list of operations needs to be provided in a service interface [11], [12]. We define a service as a set of operations and the invocation relations associated with the operations.

Definition 4 (Service) A service is defined by a 2-tuple $s = (O, T)$, where:

- $O = \{o_1, \ldots, o_n\}$ is a set of operations. Each operation $o_i \in O$ is associated with a set of messages;
- $T \subseteq O \times O$ is a set of control relations between operations. Each transition $t = (o_i, o_j) \in T (o_i, o_j \in O)$ denotes the invocation from operation $o_i$ to operation $o_j$. We call $o_i$ the origin operation of $t$ while $o_j$ the destination operation. For $t \in T$, $c(t)$ denotes the transition constraint on $t$. $t$ happens immediately after the execution of the origin operation. If $c(t) \neq \emptyset$, $t$ occurs when $c(t)$ is evaluated to be true.

Figure 1 shows two services supported by the purchase process. Figure 1(b1) is the service $s_b$ for the buyer and (b2) is the service $s_f$ for the financial institute.

C. Relations Between Process Layer and Service Layer

The internal processes and the services are coupled with each other. An internal process may support multiple services. Each activity is associated with an operation that implements the task specified by the activity. Operations that are associated with c-activities are exposed to the corresponding partners. The operations relating to a same partner are grouped as a service. A service is an external view of the internal process from the view point of a partner. Transition sequences of operations reflect the control relations between corresponding activities. For example, in Figure 1(b1), there is a transition sequence $\text{receive PayInfo, send invoice}$ in service $s_b$. The activity Receive PayInfo must precede Send Invoice in the purchase process.

III. TAXONOMY OF CHANGES

On the basis of the proposed model, two major types of changes are identified as: the service change and the process change. The classification of changes provides the foundation for change impact analysis. This section briefly introduces the identified changes.

Two major types of service changes are identified, i.e., the operation change and the transition change (cf. Figure 2). The operation change is further classified into operation existence change and operation granularity change. Operation existence change occurs due to adding or removing operations from a service. Operation granularity change refers to the change that existing operations are reorganized into different grained operations. The operation granularity change is classified into three sub types: asynchronous operation granularity change (AOGC), synchronous operation granularity change (SOGC) and complex operation granularity change (COGC). A transition change refers to the modifications of transitions between operations. Rather than discussing primitive changes, such as adding or removing a transition, we identify seven types of high level transition changes which can be accomplished by applying primitive changes. We believe high level transition changes are more meaningful for describing real world transition changes in a service.

Figure 3 shows the classification of process changes based on the proposed service oriented business process model. The change classification is identified with the consideration to facilitate the impact analysis in the service oriented environment.

IV. CHANGE IMPACT

This section presents the change impact patterns. A change impact pattern captures the effect of a specific change. The change impact patterns provide a rich intermediate results which help reduce the complexity of change
impact analysis and development of effective and efficient change reactions. Moreover, change impact patterns can be reused in the process of change analysis which is required repetitively across different locations in service based applications and information systems. In the following sub sections we will first introduce the ten change impact patterns in details and then define two functions for calculating the direct impact scopes of a service change and a process change.

A. Change Impact Patterns

A change impact pattern includes: (1) the description of the pattern, (2) the cause of the impact, (3) the direct impact scope, and (4) the change effect on the process or the services. The first five impact patterns describe the impact on the internal process caused by service changes. We describe the impact on the internal process using the the abstract control relations, which specify the required structures between c-activities. Three types of abstract control relations are defined as: abstract precedence relation, abstract conditional relation and abstract parallel relation (cf. Figure 4).

Impact pattern 1: Insert a C-activity The Insert a C-activity pattern describes that a c-activity needs to be added to the internal process. This type of impact is caused by adding an operation to a service. Four sub types of effect are identified: (i) serially inserting a c-activity between two successively executed c-activities without conditions; (ii) serially inserting a c-activity between two successively executed c-activities with conditions; (iii) inserting a c-activity in parallel to existing c-activities without conditions; and (iv) inserting a c-activity in parallel to existing c-activities with conditions. Figure 5 is an example of the impact described in (iv). Figure 5(a) is a service change and (b) is the impact on the internal process caused by the service change. The required control relations between the affected activities: $a_i$, $a_j$, $a_k$ and $a_x$ are specified by the abstract control relations.

Impact pattern 2: Remove a C-activity The Remove a C-activity pattern describes that c-activities need to be removed from the internal process. This type of impact is caused by deleting operations in a service.

Impact pattern 3: Replace C-activities The Replace C-activities pattern describes that c-activities need to be replaced by another c-activity or a set of structured c-activities. This type of impact is caused by changing operation granularity. The effect on the internal process is complicated due to the various cases of operation granularity change. The effect is classified into four sub types: (i) replacing a c-activity by another c-activity; (ii) replacing a c-activity by a set of activities. (iii) replacing a set of c-activities by another c-activity; and (iv) replacing a set of activities by another set of c-activities. Figure 6 shows an example of the impact described in (ii). The synchronous operation $a_x$ needs to be changed to asynchronous operations $a_{y1}$, $a_{y2}$ and $a_{y3}$. In such a case, the associated activity $a_x$ must be replaced with a set of structured c-activities (cf. Figure 6(b)).

Impact pattern 4: Move C-activities The Move C-activities pattern describes that existing c-activities need to be reordered. This type of impact is caused by transition sequence change, such as TSOC, SPTSC and PSTSC. The effect is classified into two sub types: (i) serially moving c-activities; and (ii) parallel moving c-activities. Figure 7
shows an example of the impact described in (ii). The transition sequence is reordered and this change requires that the associated activities are serially moved.

**Impact pattern 5: Add, Remove or Modify Conditional Branches** The *Add, Remove, or Modify Conditional Branches* pattern describes the effect that xor structures need to be modified or new xor structures need to be created. The impact is caused by transition sequence changes including ACTS, RCTS, ALTS, and RLTS. The effect is classified into two sub types: (i) embedding c-activities in or removed from a conditional branch; and (ii) embedding c-activities in or removed from a looping branch. Figure 8 is an example the impact described in (i).

The impact patterns 6-10 describe the impact on the services made by process changes.

**Impact pattern 6: Add Operations** The *Add Operation* pattern describes that operations need to be added to the corresponding services. The impact is caused by inserting a c-activity or replacing an existing c-activity in the internal process. The insertion of a c-activity or replacement of existing c-activities with new c-activities requires that operations are added to the corresponding services. The effect is classified into four sub types: (i) sequentially adding an operation in between operations without constraints; (ii) adding an operation sequentially in between operations with constraints; (iii) adding an operation in parallel to existing operations without constraints; and (iv) adding an operation in parallel to existing operations with constraints. Figure 9 is an example of the impact described in (ii). An activity $a_x$ relating to partner $p1$ is inserted between two activities in the xor structure. This change requires that the operation $o_x$ associated with $a_x$ is added between $o_{x1}$ and $o_{x2}$ with constraints in service $s_{p1}$ (cf. Figure 9(b)).

**Impact pattern 7: Remove Operations** The *Remove Operations* pattern describes that operations need to be deleted from services. The cause of this impact is the deletion of c-activities or the replacement of c-activities in the internal process. Deleting c-activities or replacing c-activities require the associated operations to be removed from corresponding services. Figure 9 also shows an example of this type of impact.

**Impact pattern 8: Change Operation Granularity** The *Change Operation Granularity* pattern describes that operation granularity needs to be modified. The impact is caused by replacing c-activities in the internal process. Replacement of activities may incur various type of operation granularity change in the services. The impact is categorized into three sub types: (i) AOGC; (ii) SOGC; and (iii) COGC. Figure 10 is an example of the impact described in (ii). The send/receive type activity $a_x$ is replaced by two send activities $a_{y1}$ and $a_{y2}$ and one receive activity $a_{y3}$. This process change makes the complex granularity change in the corresponding service (cf. 10).

**Impact pattern 9: Change Transition Sequence** The *Change Transition Sequence* pattern describes that transition sequences of the corresponding services need to be reordered. The impact is caused by moving activities, parallelizing activities or sequencing activities in the internal process. The impact is classified into three sub types: (i) TSO; (ii) SPTSC; and (iii) PSTSC. Figure 11 is an example of the impact described in (i). The activity $a_x$ is serially moved into a conditional branch. The process change causes the transition sequence to be reordered in the corresponding services.

**Impact pattern 10: Add Conditional or Looping Transition Sequence** The *Add Conditional or Looping Transition Sequence* pattern describes that constraints need to be added to exiting transitions or transition sequences need to be added between operations. The impact is caused by embedding activities in conditional branches. The effect is classified into two sub types: (i) ACTS; and (ii) ALTS.
a service fragment $s_f$ process change $S$ services (i) an internal process with $O$, process elements:

$$IFS = \{ s_f \}.$$ 

We use $B$. Direct Impact Scope

Definition 6 FuncDISS is the function: $FuncDISS : IP, S, schange \rightarrow PE$. The input of the function includes: (i) an internal process $IP$ with $CFS = (A, C, E)$ as the control flow schema and $IFS = \{ dc_1, \ldots, dc_m \}$ as the information flow schema, (ii) the set of services $S = \{ s_1, \ldots, s_n \}$ supported by $IP$, and (iii) a service change $schange$ with a set of involved operations $O_c = \{ o_1, \ldots, o_r \}$. The output of the $FuncDISS$ is a set of process elements: $PE = \{ pe_1, \ldots, pe_r \}$, where $pe_i$ ($i = 1, \ldots, r$) consists of: (i) the c-activity $a$ that is associated with $o_i$, (ii) the set of activities: $A_{depend} = \{ a_1, \ldots, a_s \} \subseteq A$, where $a_j \in A_{depend}$ such that $a \rightarrow^D a_j$, and (iii) $\forall dc_k \in IFS$ such that $dc_k$ is associated with $a$ and $A_{depend}$.

Algorithm 1 $FuncDISS$

Input $IP, S = \{ s_1, \ldots, s_n \}, schange$
Output $PE$

Let $O_c = \{ o_1, \ldots, o_r \}$ be the set of operations involved in $schange$

$PE \leftarrow \emptyset$

for all $a \in A$ do

if $a$ is the c-activity associated with $o_i$ ($i = 1, \ldots, s$) then

$DC \leftarrow \emptyset, pe \leftarrow \{ a \}$

for all $dc_j \in IFS$ do

if $dc_j$ is associated with $a$ then

$DC \leftarrow DC \cup \{ dc_j \}$

end if

end if

end for

$A_{depend} \leftarrow \emptyset$

for all $a_k \in A$ do

if $a \rightarrow^D a_k$ then

$A_{depend} \leftarrow A_{depend} \cup \{ a_k \}$

for all $dc_j \in IFS$ do

if $dc_j$ is associated with $a_k$ then

$DC \leftarrow DC \cup \{ dc_j \}$

end if

end if

end if

end for

$pe \leftarrow pe \cup A_{depend} \cup DC$

end if

$PE \leftarrow PE \cup \{ pe \}$

end for

return $PE$

Algorithm 2 calculates the direct impact scope of a service change.

V. CHANGE PROPAGATION

This section discusses the issue of change propagation. Change propagation refers to the ripple effect of change between associated services and business processes. Figure 13(a) is the change propagation of a service change. If a service change $c$ happens, $c$ is mapped to an impact pattern which captures the change effect on the internal process. Based on the impact pattern, a reaction is taken to handle $c$. Consequently further process changes $pc_1, \ldots, pc_r$ happen. Each process change $pc_i$ is mapped to an impact pattern which shows the effect on the services. Change reactions are taken and thus cause further changes on the services. Figure 13(b) is the change propagation of a process change. If a process change $c$ occurs, $c$ is mapped to the impact patterns that describe the change effect on corresponding services. For each impact pattern, a reaction is taken and thus causes further changes on the services. The following example shows the change propagation of a service change.
Algorithm 2 DISP

Input $IP$, $S = \{s_1, \ldots, s_n\}$, pchange
Output $SF = \{s_{f_1}, \ldots, s_{f_r}\}$ ($r \leq n$)

Let $A_c$ be the set of activities involved in $pchange$

Let $O^o = \emptyset (i = 1, \ldots, n)$

for all $a \in A_c$ do
  if $a$ is the c-activity relating to $p_i(i = 1, \ldots, n)$ then
    $O^o = O^o \cup \{o\}$ ($o$ is associated with $a$)
  end if
end for

for all $sf_i(i = 1, \ldots, n)$ do
  for all $o \in O^o$ do
    for all $t_j$ that associated with $o$ do
      $s_{f_i} = s_{f_i} \cup \{a_x\}$
      if $a_x$ is associated with $t_j$ & $a_x \neq o$ then
        $s_{f_i} = s_{f_i} \cup \{a_x\}$
      end if
    end for
  end for
end for

$SF = \emptyset$

for all $s_{f_i}(i = 1, \ldots, n)$ do
  if $s_{f_i} \neq \emptyset$ then
    $SF = SF \cup \{s_{f_i}\}$
  end if
end for

return $SF$

---

Example Change propagation

Figure 14 exemplifies the change propagation of a service change. A service change, Adding Conditional Transition Sequence (ACTS), occurs in service $s_{p3}$, where the operation $o_2$ is invoked conditionally. Figure 14(b) is the internal process. Based on the impact pattern, a c-activity $a_2$ needs to be embedded in a conditional branch with conditions specified by the service change. The reaction for handling the change ACTS is to add an xor structure which includes activity $a_2$ and a process fragment.

1.2. The process fragment 1.2 includes a c-activity $a_y$ relating to service $s_{p3}$. In addition, the data required by the xor connector is obtained from service $s_{p2}$ and thus an activity $a_x$ is inserted before the xor structure. As shown in the Figure 14(c), the reaction causes further changes to service $s_{p2}$ and $s_{p3}$.

Based on the change propagation, the actual impact scope of a change can be derived. The actual impact scope of a process change is its direct impact scope. The function $FuncAISS$ is defined to calculate the actual impact scope of a service change.

Definition 7 $FuncAISS$ is the function: $FuncAISS : IP, S, change, PCHANGE \rightarrow PE, SFS$. The input of the function includes: (i) an internal process $IP$, (ii) the set of services $S = \{s_1, \ldots, s_n\}$ supported by $IP$, (iii) a service change $change$, and (iv) a set of process changes $PCHANGE = \{pchange_1, \ldots, pchange_r\}$ that are caused by reactions for handling the service change $change$. The output of $FuncAISS$ includes: (i) a set of process elements $PE$, where $PE = FuncDISP(IP, S, change)$, and (ii) a list of service fragments $SFS = \{SF_1, \ldots, SF_h\}$, where $SF_i = FuncDISP(IP, S, pchange_i)(i = 1, \ldots, h)$.

VI. RELATED WORK

Change management has been widely studied in the context of workflow and information systems [13], [14], [10], [15]. Many existing works focus on the evolution of process schemata and the strategies of process instance migration. Process adaptation and flexibility are also studied for reacting to changes [16], [17]. Existing works about service change management cover service interface and business
protocol adaptation [18], [19], [20], change management for BPEL process orchestration and choreography [3], [4], virtual enterprise [7], and business protocol evolution [21] and service evolution [5], [6]. These works only concentrate on the change issues of services or business processes respectively. They are inadequate to address the issues of change management in the SOC environment where change management becomes more critical and challenging due to the distributed and dynamic natures of services and business processes.

There are various types of dependencies between services and business processes in service based applications and information systems. Change analysis and change reactions are difficult due to the possible complex dependencies between services and business processes. This work proposes an approach of the change impact analysis for a typical case that multiple services are supported by a single business process.

VII. CONCLUSIONS

This paper reports our work on change impact analysis for service based business processes. A typical case of the dependencies between services and business processes is highlighted when multiple services are supported by a single business process. Ten change impact patterns are specified and the functions for calculating the impact scope of a specific change are defined. Change propagation between associated services and processes is studied on the foundation of the identified change impact patterns. These change impact patterns are intermediate results in the analysis process and they can be reused in development and maintenance of applications and information systems. They are helpful to reduce the complexity of change analysis. For the future work, we will carry out extensive investigation about complicated structures and dependencies between services and business processes.

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