Business Process Modeling: a Service-Oriented Approach

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ABSTRACT
This research concerns the definition of a service-oriented approach for business processes modeling. Business services are reusable process units that contain one or several process fragments for satisfying business goals. Business services may be composed in various manners to satisfy business process designer's needs. A goal-oriented business service model supports business knowledge representation for specifying and composing business services. Ontologies for business systems domain provide a common vocabulary for matching business process designer's request and available business services. A service composition process organizes the discovery, the selection and the assembly of business services to dynamically build business processes tailored to business designer's requirements.

General Terms
.Services, process modeling

Keywords
Business process modeling, business services, ontologies, composition process.

1. INTRODUCTION
Business process modeling is often used, on the one hand, to automate business processes for more productivity, and on the other hand, to evaluate and improve existing business processes.

The business process modeling domain is undergoing a dramatic change [11][12][9][10]. The demand for customizing to enterprise needs has led to rethinking business process modeling. Flexibility is becoming a new guiding principle in the design of business processes. With this principle, an enterprise could respond to any customer requirements adapting business processes "on demand".

Workflow approaches, usually used for business process modeling, are criticized for their rigid process description. They fall under the static composition category in which activities and flow management are specified a priori, therefore they lack flexibility in tailoring process to enterprise needs [15] [18].

Flexibility could be reached by reusing business services that encapsulate business process fragments. Business services are existing semantic components that can be selected and composed "on demand" to define new business processes tailored to enterprise needs. Automation of business services selection and composition is achieved by describing the services semantically, thus allowing software agents to reason about the service capability.

Thus, our objective is to develop a Business Service Oriented Approach (BSOA) for designing business processes. This approach is based on three key principles: (i) service orientation to define and manage process components, (ii) reuse of existing business services and (iii) dynamic composition of services for generating tailored processes.

A business service is a piece of business process [2][19] for satisfying a business goal. Goal orientation, in specifying services, emphasizes service usage and customer satisfaction. Thus, goal orientation reduces the gap between available business services and business process designer (BPD)'s intentions. In BSOA, process modeling consists in composing, on the fly, business services. Thus, dynamic composition is suitable for designing new processes tailored to the particular context of a project compagny. During composition, the process guides business process designer's choices ; it selects business services and delivers a process fragment that achieves a BPD's requirement. In this approach, dynamic composition is achieved by using a semantic approach for business service description. For example, the goal orientation used in business service specification supports matching BPD's intention and business services during service discovery.

The remainder of this paper is organised as follows: section 2 discusses workflow approach and service-orientation for business process modeling. In section 3, we introduce the main components of BSOA. Section 4 presents both the business service model for describing business services and the ontologies for business systems domain. Section 5 specifies the service composition process for building tailored business processes.

2. RELATED WORK
The literature on business process modeling is large and diverse [11][9][12][7]. This section provides a brief overview of the two main approaches, the one created before the development of Web services (the workflow approach) and the other one based on Web services and service-oriented architecture.

In workflow approach, business processes are pre-specified [18]. A workflow process can choreograph a set of activities that often result in intangible outcomes or benefits. Languages closer to workflow approach are, for example, BPEL (Business Process Execution Language) and FDL (Flow Definition Langage). Workflow approach is criticized for its rigid process specification. They pre-define activities and control within business processes specification which are not tailored towards particular enterprise needs.

Recent work in the domain of Web services provides a suitable technical foundation for making business processes accessible within

enterprises and across enterprises. This work increases the need to consider a service-based modeling approach of business processes. Web services correspond to reusable software components used to implement activities within a business process [11][2]. However existing Web services models lack a semantic level which would support business knowledge representation.

In this paper, we propose a business service model and a service composition process. The service paradigm offers a flexible approach in reusing existing business processes and modeling new ones [8][5]. It allows dynamically building business processes by combining existing services tailored to enterprise needs.

3. OVERVIEW OF BSOA

This section introduces the main elements of the business service oriented approach (see Figure 1) for modeling business processes.

3.1 Main elements of BSOA

Ideally, given a BPD's request and a set of existing business services, the composition process would discovery a collection of services that achieves the request. Both business services descriptions and requests share a common vocabulary specified in ontologies.

The **business services base** contains a set of services called business services. A business service is a reusable unit that contains one or several process fragments to solve a business problem. For example, a business service could specify a process fragment to plan delivery rounds. The business services are described with a semantic service model. The goal orientation in service specification makes very different services and components. Goal orientation emphasizes service usage and customer satisfaction. In our approach, business services help a BPD in carrying out business processes modeling.

BSOA uses also **task ontologies** which provide a common vocabulary for specifying both business services and BPD's requests. There is a need for ontology when applying search and semantic matching for business services. Ontologies in this approach concern the domain of business systems. They enable to define a set of terms relating to four dimensions of business modeling [6]: the business goal ontology L_{goal}, the business actor ontology L_{act}, the business process ontology L_{proc} and the business resource ontology L_{res}. These ontologies are inter-dependent ; for instance actors from the business actor ontology are related to activities defined in the process ontology. The four ontologies are described with OWL [3].

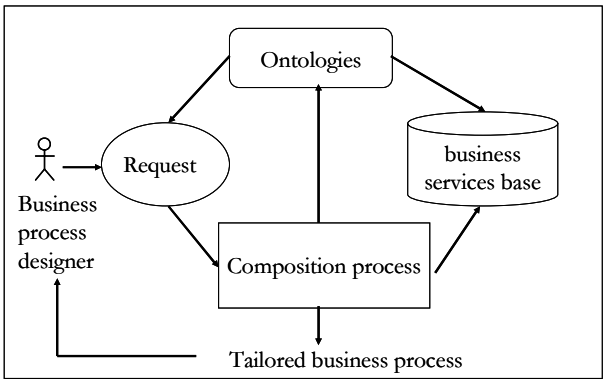

Figure 1. Overview of the business service oriented approach

3.2 Features of BSOA

This approach supports **semantic description of business services**. Using semantic descriptions not only helps in efficiently finding relevant services, it also helps in reasoning about them. For instance, the goal orientation used in defining services enables to consider a set of services having a same finality and compare the different manners provided by these services to achieve it.

In BSOA, adding semantics to business service description is achieved by using **ontologies** that support shared vocabularies on business for use in the service description. Using ontologies, the semantics implied in business service descriptions can be made explicit. Hence while searching for a business service; relevant business ontologies can be used to enable semantic matching of services. The BSOA approach provides support for this kind of matching by relating both business services descriptions and business process designer requirements to ontologies.

BSOA provides a business service model where the processes are represented using **abstraction mechanisms** which allow the specification of generic processes for different situations. The service model also enables personalization of the processes based on decision and variation points used at the operational level in service specification.

Finally, the composition process supports business process design. The **composition process is goal-oriented**; it suggests the designer to use the business goal ontology for specifying requests. Service composition consists of goal operationalisation. Business services are discovered and selected to achieve the goals which contribute to the satisfaction of the request.

In summary the fundamental assumption in our work of modelling business process with services is that services are reusable process chunks that can be semantically described, discovered and composed for satisfying each designer request.

4. BUSINESS SERVICE MODEL AND TASK ONTOLOGIES

This section defines briefly the service model and the task ontologies.

4.1 The business service model

This section defines briefly major concepts used in business service specification. The description of a business service contains three parts (see Figure 2): a **profile part**, a **structure part** and a **process part**. A service delivers a process to achieve a certain goal by using resources. The three parts express business knowledge at different abstraction levels: the profile part emphasizes the business problem that the service solves, the structure part characterises a manner to solve the problem and the process part provides a reusable process fragment. Profile and structure parts increases semantic description of business services in order to enable the automation of business service discovery and composition.

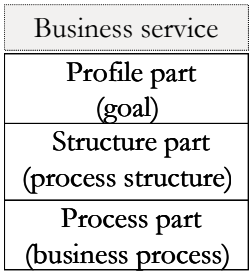

Figure 2. A business service

4.1.1 The profile part

This part defines the purpose of the service. Our approach for designing services is based on a "customer" point of view. So, the profile part contains contextual knowledge on "why" the customer (i.e. the BPD) takes advantages in using the service. Profile part (see Figure 3) is largely used during discovery and selection of business services. The profile part contains two kinds of knowledge: finality and argument.

The **finality** defines the problem that the business service solves. The finality is structured with a goal (defined in the business goal ontology), a manner and a context. A goal is considered as a business goal ie. a compagny's goal. We will refer to this interpretation when we use the term "goal" (with no prefix) in the remain of the paper. Each goal is defined by a verb and an object [17]. For example, the goal *"Schedule delivery rounds"*, is defined with the verb *"Schedule"* and the object *"delivery rounds"*. The **manner** defines a way of achieving the goal and the **context** describes the business project situation for which the business service is suitable. The context is detailed with the business project nature, the involved actors, a process phase and some resources. All these elements refer to ontologies.

Finally, the **arguments** express the advantages (ie. the "**pro**" arguments) and the drawbacks (ie. the "**con**" arguments) of using the business service. So, arguments support service(s) selection within the goal realization process.

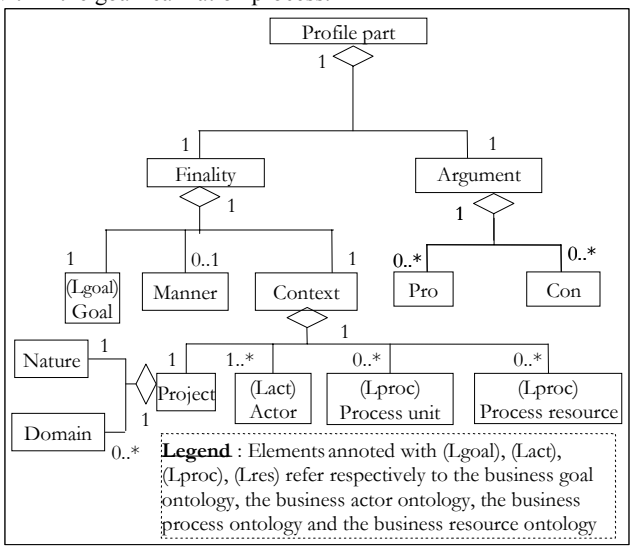

Figure 3. Profile part elements

For instance, the profile part of the business service *"Schedule delivery rounds"* is presented in figure 4. This service helps the BPD to plan delivery rounds.

-Finality
- **-Goal** : Schedule delivery rounds
- **-Manner** : -
- **-Context** :
  - **- Project** :
    - **- Nature** : Delivery
    - **- Domain** : Supply chain management
  - **- Actor** : Planner
  - **- Process unit** : Analysis
  - **- Process resource** : Delivery note

-Argument :
- **-pro** : the suggested business process guides delivery planning
- **-con** : -

Figure 4. Profile part of the business service "*Schedule delivery rounds*"

4.1.2 The structure part

This part describes a process organization for achieving the service goal. The structure part contains three elements (see Figure 5): an initial situation, a final situation, and a process structure.

The **initial situation** indicates pre-conditions and resources necessary to process realisation. The **final situation** specifies the results and the post-conditions of the process. The initial and final situations are described with process ontology terms.

A **process** structure can be atomic, composite, simple or decisional.

Atomic processes realize elementary goals ; these goals are not decomposable into sub goals. An atomic process is considered as an operational process.

Composite processes correspond to complex goals ; they contain constituent processes organized with control constructs. Control constructs indicate the manner in which constituent processes are executed. In this service-oriented approach, consituent processes execution may be in sequence (i.e. in a specific order) or in parallel (i.e. without a particular order). Constituent processes within a composite process may be atomic or simple.

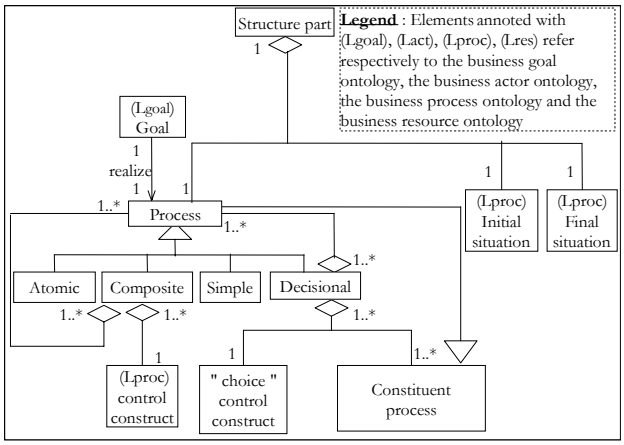

Figure 5. Structure part elements

Decisional processes are a specific case of composite processes. Decisional processes propose several alternative decompositions of a goal. Each decomposition is characterised by quality attributes that assist BPD in making his choice. Decisional processes offer different manners to satisfy the same goal. Decisional processes are suitable for variability. At composition time, the BPD has to choose one or several constituent processes to achieve his objective.

Simple processes allow differing process realization in other services. Only at composition time, the simple process is associated to a service supporting its realization. Simple processes are powerful mechanisms to achieve flexibility in process specification. They also provide the ability to adapt a process to different contexts. Indeed, at composition time, the simple process will be substituted with the more suitable service.

We illustrate the process part in figure 6 with the composite process *"Schedule delivery rounds"*. It has four constituent processes organized in sequence. One constituent process is simple, the other ones are atomic.

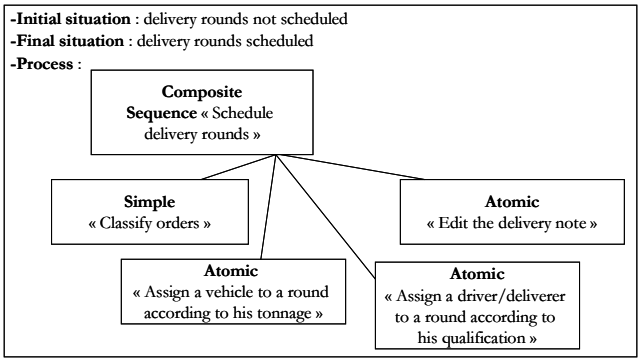

Figure 6. Structure part of the business service "*Schedule delivery rounds*"

4.1.3 The process part

This part defines the solution (i.e. a process fragment) offered by the service. The solution is an executable process described in terms of activities and business objects. This part is composed of resource descriptions and an execution graph (Fig. 7).

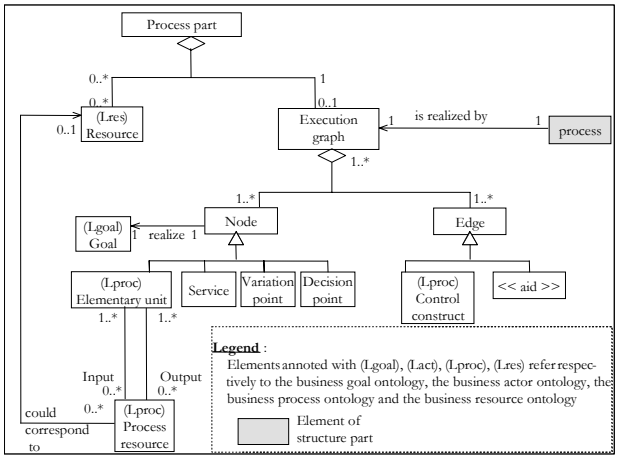

Figure 7. Process part elements

Resources correspond to elements which are used or delivered by the process. Resources are described with the business resource ontology. The execution graph is a kind of activity diagram [4] including variation points and decision points that represent respectively simple processes and decisional processes defined in the structure part.

In the execution graph given in figure 8, the variation point corresponds to the simple process *"Classify orders"* defined in the structure part (see Figure 6). At composition time, this variation point will be substituted with the execution graph of the service chosen by the BPD. This mechanism enables to generate business processes tailored to BPD's requirements.

The goal orientation of the business service model enables to reduce the gap between the BPD's requests and the available services. The business service model proposes abstraction mechanisms for both the flexibility of processes and the ability to adapt processes to different circumstances.

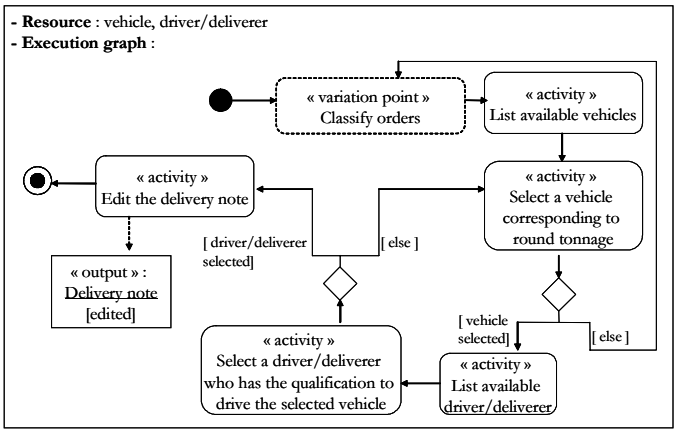

Figure 8. Process part of the business service *"Schedule delivery rounds"*

4.2 Ontologies for business systems

This section presents the ontologies for describing various aspects related to business services. They support the research and composition of business services with a high degree of automation. In this approach, ontologies provide also a common vocabulary which can be used both by the "providers" and the "requesters" of services.

The four ontologies are task ontologies [13] for the domain of business systems. These ontologies specify knowledge on business problems and solutions. They provide a vocabulary to describe activities at a domain-independent level. This independence is essential to describe the services at a process level. The second motivation to use task ontologies is in the possibility to consider BPD's needs as problems to solve. Finally, these ontologies play an important role in matching BPD requests and available services.

Knowledge on business is structured in four related ontologies:

The **business goal ontology L_{goal}** defines a vocabulary on the business problems (see figure 9). For instance, *"Schedule delivery rounds"* is a business goal which can be achieve in different manners.

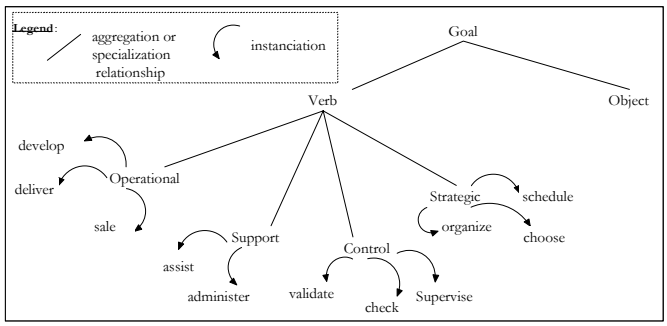

Figure 9. Partial business goal ontology

Business problems are represented with a goal-oriented approach, thus business problems are goals to achieve. Goal ontology provides a hierarchy of goal classes: operational, support, control and strategic. Instances of this ontology are used to define both the goals of business services and BPD' requests. Goals are structured with a verb and an object.

The **business actor ontology L_{act}** defines roles for the actors involved in business process. Instances of this ontology are used in service specification to indicate the actors who are concerned by the service. The actor can be internal or external to the business company (see Figure 10). Internal actors belong to the business

domain and are responsible in business activities execution. External actors may participate in the business process to realize some activities or may be the beneficiaries of the business process realization.

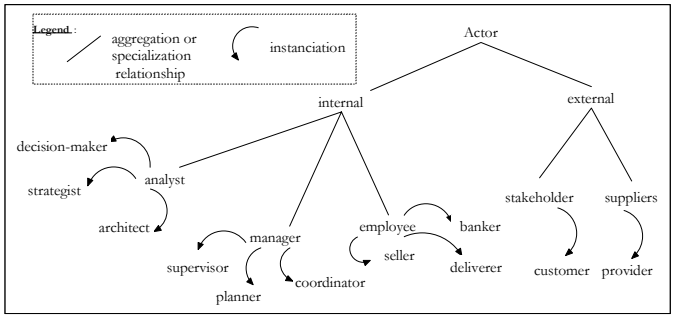

Figure 10. Partial business actor ontology

The **business process ontology L_{proc}** defines a common terminology for the description of the business activities (and their organization). This ontology is, in particular, used in service specification to describe the control constructs of processes (see Figure 11).

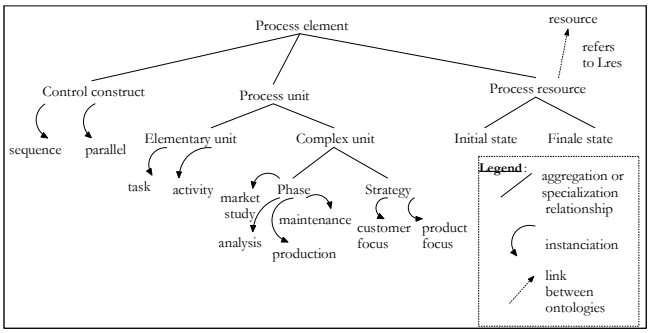

Figure 11. Partial business process ontology

The **business resource ontology L_{prod}** defines a common vocabulary for characterizing all the elements used and produced during business processes execution (see Figure 12). This ontology is used, in particular, to specify inputs and outputs of the processes within the service process part.

On one hand, the four ontologies provide terms that support business services specification, on the other hand, the business service model prescribes a structure for each business service.

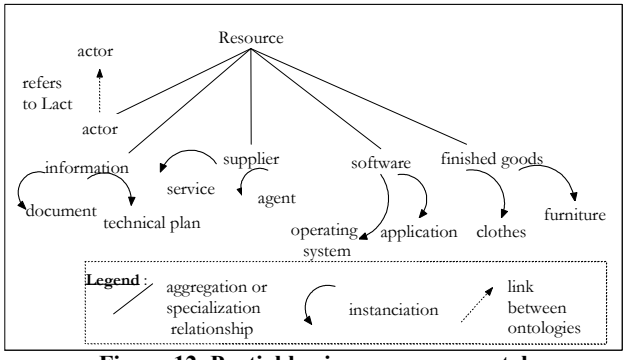

Figure 12. Partial business resource ontology

5. BUSINESS SERVICE COMPOSITION

The service orientation gives a new way in process modeling: process modeling consists in composing business services to satisfy a particular request. Business services are considered as process fragments, so they can be composed to build complex processes. The objective of service composition is to create new business processes by combining processes within existing services. Service composition is generated on the fly based on a BPD's request. This approach is in contrast to the solutions provided by classical workflow approaches where activities in a process are pre-planned and pre-specified [1][16][14].

In this approach, service composition is seen as an iterative process. The **entry** of this process is a request formulated by a BPD. The treatment of the request consists in searching, selecting and organizing all the services necessary for satisfying the request. Because the request is a goal, request satisfaction is considered as a goal composition/decomposition process. We call "service composition graph" (Gc), a graph that specifies all the services and their relationships participating to request satisfaction.

Service composition results in a whole business process (or a fragment) generated from the execution graphs of the services appearing in the service composition graph. The **result** is represented by a business process graph (Gp). The business process graph can be executed in a certain context to realize a business goal.

5.1 The service composition graph (Gc)

The service composition graph (Gc) emphasizes all the services found and chosen by the BPD during the service composition process. This graph is dynamically built in an incremental way at composition time for satisfying a particular BPD's request.

Let us note that this graph expresses links between services. These links only exist to satisfy a particular request. Besides, the same request can lead to several service composition graphs corresponding to different contexts and to different BPD's choices.

We define a service composition graph as a tree (see Figure 13) ; the root is the initial BPD's request. Recall that a request is a goal expression based on the business goal ontology.

-Nodes in Gc can be business services or business services compositions. Service nodes correspond to existing services in the services base ; they match to sub goals resulting from the initial goal decomposition. These nodes are labelled with the service name and its type (decisional, atomic and composite).

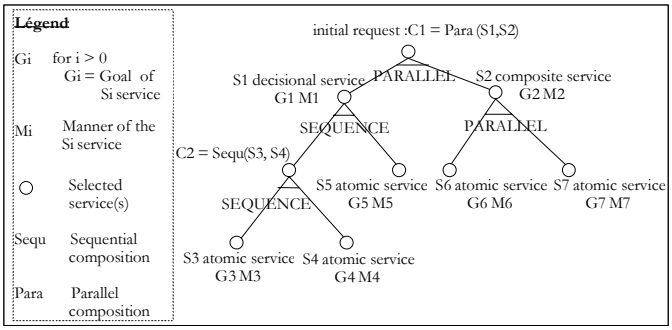

Figure 13. Service composition graph example

Service composition nodes represent a set of services chosen by the BPD to realize a particular goal. At service composition time, the BPD has to choose a type of composition. A service composition

can be sequential or parallel. A composition is sequential when the BPD wishes to define an order between services. A composition is parallel when the services are independent. These nodes are labelled with the type of composition and the list of the constituent services. For example, "C1=Para(S1,S2)" is a parallel composition of S1 service and S2 service. This case appears for instance if a BPD has chosen the S1 service *"Classify orders optimizing the number of kilomeers travelled"* and the S2 service *"Classify orders respecting customers' constraints"* to realize the goal *"Classify orders"*.

- Edges in Gc indicate the composition links between services (or service compositions). The service composition graph uses two types of link:

- The **"SEQUENCE" link** indicates that services are ordered. This link is used when a node is a decisional or composite service with a sequence control construct in its structure part. For example, the "SEQUENCE" link between the service composition *"C2= Sequ (S3,S4)"* and the S5 service (in figure 13) results from the S1 service ; this service contains a decisional process with a sequence control construct.

- The **"PARALLEL" link** indicates that services are independent ; they can be used in a parallel way. This link can result from a decisional or a composite process with a parallel control construct. For example, the "PARALLEL" link between the S6 service and the S7 service comes from the S2 service ; it has a composite process whose control construct is "parallel".

The leaves of Gc are atomic services obtained at the end of the composition process execution. The service composition graph gradually grows by composing the selected services during the composition process.

The service composition graph makes possible to derive the business process graph which is the result of the composition process. Derivation is based on equivalence rules between service composition graph and business process graph (see Figure 14).

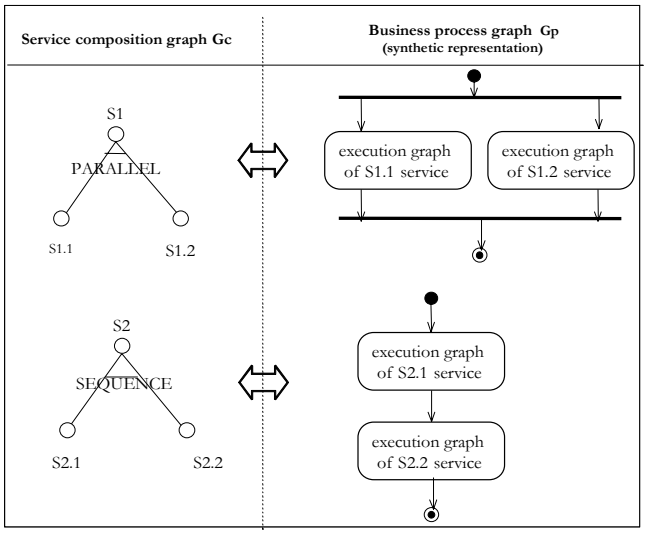

Figure 14. Equivalence between the links of the service composition graph and the links of the business process graph

The following section details the composition process ; it shows how the composition graph and the process graph are built at composition time.

5.2 Composition process activities

The service composition process is an iterative process. At each iteration, the service composition graph (Gc) is extended and the business process graph (Gp) is refined. Each iteration is driven by a goal. During the first iteration, the goal is the request one. In the following iterations, the goal results from one (or some) simple process(es) defined in a composite or decisional process of a business service. Recall that a simple process is an abstract process that can be realized in several manners. The principle of dynamic composition consists in comparing the simple process with potentially matching services. Alternative services may be generated, one or more services can be chosen by the BPD according the criteria defined in the business service contexts. This type of composition is specified on the fly and requires dynamically structuring and choosing services.

Each iteration in the composition process contains three activities: discovery, composition and refinement (see Figure 15). These activities are repeated until the initial request is satisfied with a set of services. The number of iterations varies according to the granularity of the goal in the request. Indeed, the more general will be the goal, the more important will be the number of services in the composition graph and the number of iterations in the composition process.

Discovery: This activity consists of goal definition and service matching (see figure 16).

During the first iteration, the goal ontology L_{goal} guides the BPD in request formulation. Moreover, the goal ontology allows checking that the formulated request respects the structure of a goal (ie. a verb followed by an object). In the following iterations, goals directly result from simple processes.

Service discovery consists in comparing the desired goal with the goal of the business services available in the services base. If the original goal does not correspond to any business service, it is analyzed using the business goal ontology and the business resource ontology. On the one hand, the goal ontology L_{goal} makes it possible to search services which have a similar verb with the goal one. On the other hand, the resource ontology L_{res} enables to analyze the object of the goal.

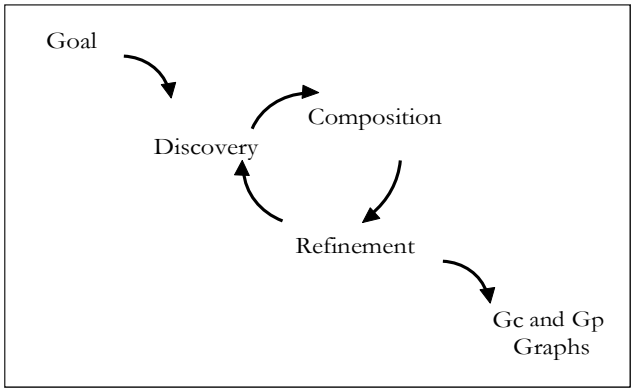

Figure 15. Iteration in composition process

Discovery of services matching the goal may result in alternative solutions i.e. several possible set of services satisfying the goal.

Composition: The composition activity consists in service selection and service composition (see figure 16).

Discovery of services matching the current goal may result in alternative solutions. For each solution, service profile description

(manner, context and arguments) is available to guide BPD's choices. At this stage of the composition process, the chosen services contribute to the initial request satisfaction. These services can be atomic, composite or decisional (i.e. the structure part of these services may be an atomic process, a composite or a decisional process). At this stage, these services can be composed in order to achieve the current goal of the iteration. The service composition graph is extended with selected services.

Refinement: Extension of the service composition graph leads to business process graph refinement (see figure 16). Indeed, refinement consists in substituting the variation points (or decision points) by the corresponding execution graphs of the constituent services. Then, the links defined in Gc must be carried over in Gp. For each process within the selected services in the current iteration, new iterations are initialized according to different situations:

- If the process **is decisional**, the developer must select one or more simple constituent processes. Quality attributes, defined for each constituent process of the decisional process, guide BPD's choices. For all simple processes selected by the BPD, a new iteration is initialized with goals corresponding to simple processes. It is important to note that the execution graph of the current decisional service (and consequently of the business process graph) comprises a decision point. This new iteration will enable to substitute the decision point of the business process graph with the execution graph of the found services.

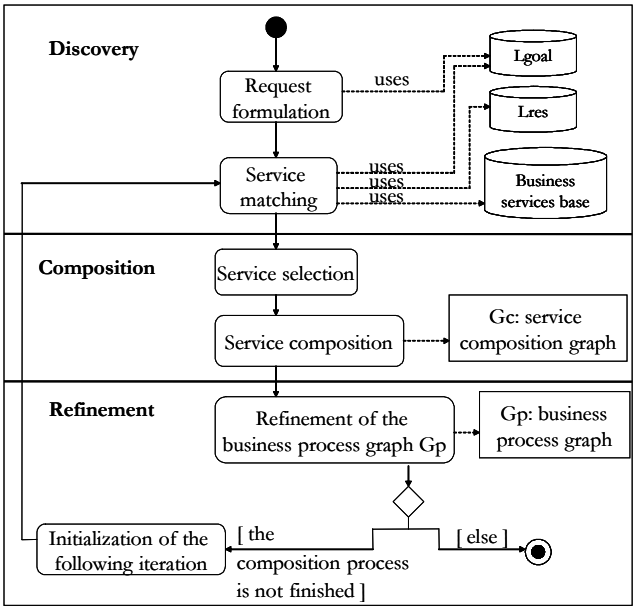

Figure 16. Definition of an iteration in the composition process

- If the process **is composite**, it has one or more simple constituent processes. Similarly to decisional processes, a new iteration is initialized with goals corresponding to simple processes. In this new iteration, the process will search the services which are appropriated to replace the simple processes. It is important to note that the execution graph of the current service (and consequently the business process graph) comprises a variation point for each simple process. The following iteration will make it possible to substitute the variation points of the business process graph with the execution graphs of the selected services.

- If the process **is atomic**, either the composition process is finished or it remains variation points or decision points in the business process graph and new iterations are necessary.

It is important to note that simple processes, as constituent of decisional processes or composite processes, initiate new iterations in the composition process. Simple processes lead, at composition time, to explore the services base to find the service the more suitable to realize the request. In this way, at any time, composition takes into account the current state of the services base.

At the end of the composition process, the business process graph does not comprise any more variation point or decision point. The business process graph obtained could be carried out to realize the business compagny goal.

6. CONCLUSIONS AND FUTURE WORK

In this paper, we have presented a business service oriented approach for modeling business processes tailored to BPD's requirements. Business problems are considered as goals that a business compagny wants to realize and business services are self-contained units that provide process fragments to achieve these goals. Four task ontologies for business systems support the research and composition of business services with a high degree of automation. Furthermore, ontologies provide a common vocabulary which can be used both by the "providers" and the "requesters" of services. Service composition is carried out by an iterative composition process which dynamically links services to generate tailored business processes.

For future research, we will focus on dynamic evolution of the task ontologies. During service design and request formulation, new terms could be automatically added to ontologies in order to extend the vocabulary used by "requesters" and "providers" of services. Another research perspective has been initialized to define a methodological approach for designing business services from a service composition graph. In parallel our work focuses on providing an engine for controlling the service composition process by using AI planning techniques.

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