Using UML to Specify Artifact-centric Business Process Models

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Keywords: Business Artifacts, BALSA Framework, UML, Business Process Modeling

Abstract: Business process modeling using an artifact-centric approach has raised a significant interest over the last few years. One of the research challenges in this area is looking for different approaches to represent all the dimensions in artifact-centric business process models. Bearing this in mind, the present paper proposes how to specify artifact-centric business process models by means of diagrams based on UML. The advantages of basing our work on UML are many: it is a semi-formal language with a precise semantics; it is widely used and easy to understand; and it provides an artifact-centric specification which incorporates also some aspects of process-awareness.

1 INTRODUCTION

Business process models have been traditionally based on an activity-centric or process-centric perspective, defining how a business process or workflow is supposed to operate, but giving little importance to the information produced or needed by the process (Damaggio et al., 2011).

In contrast, the artifact-centric (or data-centric) approach to process modeling considers data as a key element in the business process specification. Business artifacts, representing the data, model key business-relevant entities which are updated by a set of services that implement business process tasks. The main advantage of artifact-centric business process models over process-centric approaches is that it is possible to perform semantic reasoning on the model. That is, the meaning of the tasks can be formally defined and it is possible to automatically check for any inherent contradictions in their definition. The artifact-centric approach to business process modeling has been successfully applied in practice (Bhattacharya et al., 2007a) and it has been shown to have a great intuitive appeal to business managers and to system developers.

To facilitate the analysis of artifact-centric process models, (Hull, 2008; Bhattacharya et al., 2009) proposed the use of the BALSA (**B**usiness **A**rtifacts, **L**ifecycles, **S**ervices and **A**ssociations) framework. This framework establishes the common ground for artifact-centric business process modeling by defining four different dimensions which, ideally, should be present in any artifact-centric process model:

- **Business Artifacts.** They represent meaningful data for the business, and as such they hold information needed for the process. Each artifact corresponds to a real life entity, and therefore may be related to other business artifacts. A business artifact has an identity and its progress through the workflow can be tracked.
- **Lifecycles.** Lifecycles represent the evolution of an artifact, showing the relevant stages in its life, from the moment it is created until it is destroyed or archived.
- **Services.** They represent tasks (i.e. meaningful units of work) that evolve the artifact in order to achieve the process's goals. They create, update and delete business artifacts.
- **Associations.** Associations represent constraints in the manner how services make changes to artifacts. This means that associations can restrict the order in which services are executed. They may be specified using a procedural specification (e.g. a workflow) or in a declarative way (e.g. condition-action rules).

Notice that, for the remainder of this work, we use the term *service* with the meaning defined above, which differs from its definition in Service Science.

One of the research challenges in artifact-centric business process modeling is to find the "best" model

EstaÃśol M., Queralt A., Sancho M. and Teniente E.
Using UML to Specify Artifact-centric Business Process Models.
DOI: 10.5220/0005424600840093
In *Proceedings of the Fourth International Symposium on Business Modeling and Software Design (BMSD 2014)*, pages 84-93
ISBN: 978-989-758-032-1

(Hull, 2008), seeing that none of the existing approaches can handle the number of requirements of business process modeling. After an extensive analysis, we realized that the majority of work that has been done in this area is based on complex mathematical or logical languages to represent the processes. Although they are practical from a formal perspective, these languages are difficult to understand and not intuitive for business people.

For this reason, in this paper we propose a way to represent artifact-centric business process models such that:

- It is a high-level representation.
- It is independent from the final implementation of the business process.
- It represents most of the BALSA dimensions in a graphical, intuitive way.

We do so by mapping each of the dimensions in the BALSA framework to a graphical model, if possible. We will define these models using the UML language as a basis because of its expressiveness, although they could be defined using a different notation. UML is an ISO standard (ISO, 2012) and it is also the *de facto* standard for software modeling. Although initially conceived for software modeling, we have found that it adapts easily to artifact-centric business process modeling, as we can use it to represent both the static structure and the dynamic behavior of the process. Those aspects that cannot be represented graphically using UML will be specified using OCL (Object Constraint Language) (ISO, 2012). Although they could be represented using another language, we use OCL because it integrates naturally with UML and it does not have the ambiguities of natural language.

This paper extends our previous work in (Estañol et al., 2013) by describing in detail the characteristics of the models we use to define artifact-centric business process models using UML as a basis. We also provide a detailed comparison of our proposal to previous work, and we include some process-centric approaches in the review.

The rest of the paper is structured in the following way. Section 2 presents our proposal for artifact-centric business process models using UML. In order to illustrate it, we will use a running example based on a city bicycle rental system. Section 3 analyzes and reviews the related work. Finally, section 4 states the conclusions and describes some further work.

2 ARTIFACT-CENTRIC BUSINESS PROCESS MODELS IN UML

One of the pending challenges in artifact-centric business process modeling is to find the best model to represent each of the dimensions of the BALSA framework (Hull, 2008). This section describes in detail how UML and OCL can be applied to define an artifact-centric process model following this framework. From this process we obtain a platform-independent model (a term we borrow from model-driven architecture to refer to a model that is independent of the final implementation platform) which is detailed enough to show how the artifacts evolve and the effect of services on them.

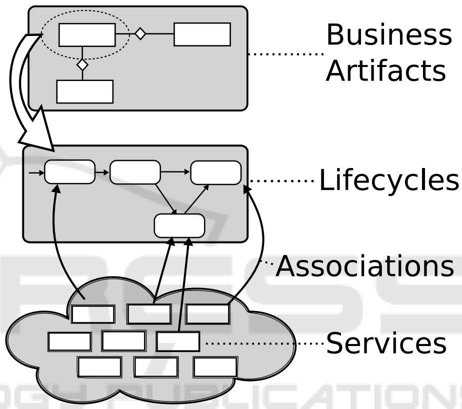


Figure 1: Generic representation of the dimensions in the BALSA framework.

Figure 1, adapted from (Hull, 2008), shows the different BALSA dimensions and how they relate to each other. We start by defining the business artifacts and how they are related to other objects. More specifically, we will determine their attributes, the relationships between them, and their identifiers (for both the artifacts and the objects). Once we have this, for each business artifact, we will define its lifecycle. This should give us an overview of the different events that trigger the transitions between states. After this, it is time to specify the services that make up these events and to establish the conditions or the order of their execution (i.e. the associations).

We will illustrate our approach by means of a real-life example, based on a city bicycle rental system, such as Bicing. Bicing is a service offered by the Barcelona City Council to registered users as an alternative form of transport. Bicycles are docked to stations placed around the city, so that users can take a bicycle form a certain station and return it to a different one. For the purpose of our example, we will consider that users are automatically blacklisted if they do not return a bicycle within three days after taking it.

2.1 Business Artifacts as a Class Diagram

Business artifacts represent the relevant data for the business. A business artifact has an *identity*, which makes it distinguishable from any other artifact, and can be tracked as it progresses through the workflow of the business process execution. It will also have a set of *attributes* to store the data needed for the workflow execution. Business artifacts may be related to other business artifacts and objects. The main difference between a business artifact and an object is that the business artifact has an associated lifecycle showing its evolution, whereas the object does not. In business terms, an artifact represents the explicit knowledge concerning progress toward a business goal at any instant.

The conceptual schema of business artifacts is intended to hold all the information needed to complete business process execution. Business artifacts and objects are similar to domain concepts because they represent real-world entities. As domain concepts can be represented in a class diagram, we will be able to represent business artifacts and objects in the same way. In particular, we will use a class diagram based on UML, which will allow us to represent, in a graphical way, the following elements:

- **Classes**, which correspond to business artifacts or objects.
- **Attributes** for each of the classes, which contain relevant information for each domain concept.
- **Relationships** between classes, showing how they relate to each other.
- **Integrity Constraints**, which establish restrictions over the classes, the attributes or the relationships between them. Constraints can be represented either graphically, in the diagram itself, or textually in OCL or in natural language.

Figure 2 shows the class diagram that corresponds to our bicycle rental system example. The business artifact in our example is *Bicycle*, as it keeps the information of the key elements needed to provide the service: the bicycles themselves, which are identified by their *id*. Apart from the business artifact, there are several objects, such as *AnchorPoint* (identified by *number* and *Station*, according to constraint 3), *User* (identified by *id*) and *Station* (also identified by *id*). For each artifact or object, we will have as many attributes as relevant information we want to keep about it.

The evolution of a business artifact is recorded in the class diagram by means of subclasses. The use of subclasses makes it possible to have exactly the attributes and relationships that are needed according to the artifact's state, preserving at the same time its original identifier and the characteristics that are independent of the artifact's state which are represented in the superclass.

In our example, the business artifact *Bicycle* has four subclasses: *Available*, *InUse*, *Lost* and *Unusable* which keep track of the different stages of the *Bicycle* while containing information which is relevant only for that particular stage. For instance, when a bicycle is *InUse*, it is linked to a certain *User* and has an attribute that stores when it is expected to be returned. These subclasses also require restrictions to ensure that the dates are coherent: we do not show each of the restrictions due to space limitations.

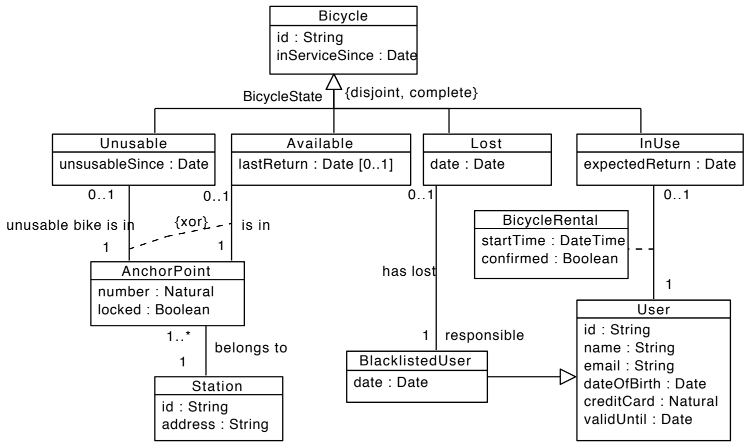
Notice that *BicycleRental* is an association class: it results from the reification of a relationship (i.e. viewing it as class) between two or more classes (Olivé, 2007). Association classes are particularly useful when we want to record additional information about a relationship, as it is the case here. They are identified by the classes that take part in the relationship; in this case, *InUse* and *User* (identified by its *id*).

2.2 Lifecycles as State Machine Diagrams

The lifecycle of a business artifact states the relevant *stages* in the possible evolution of the artifact, from inception to final disposal and archiving, as far as the business process is concerned. It is natural to represent it by using a variant of state machines, where each state of the machine corresponds to a possible stage in the lifecycle of an artifact from the class diagram (Hull, 2008).

Therefore, for each business artifact in our class diagram, we will have the corresponding state machine diagram representing its lifecycle. Taking as a basis UML state machine diagrams, our diagrams consist of:

- **States.** They represent the stages in the evolution of a class or business artifact. Therefore, a state machine diagram will have as many states as relevant subclasses the business artifact has in the class diagram.
- **Transitions.** Transitions, represented as arrows, connect the different states (i.e. stages of the busi-



1. *Bicycles* are identified by their *id*: `context Bicycle inv: Bicycle.allInstances()-> isUnique(id)`
2. *Users* and *Stations* are identified by their respective *id*: `See restriction 1.`
3. A *Station* cannot have two *AnchorPoints* with the same number:
   `context Station inv: self.anchorPoint->isUnique(number)`
4. A *BlacklistedUser* cannot have any *BicycleRentals*: `context BlacklistedUser inv: self.bicycleRental->isEmpty()`
5. Dates should be coherent: `Several OCL constraints would be required.`

Figure 2: Class diagram showing the business artifacts as classes with the corresponding integrity constraints.

ness artifact) in the state machine diagram. Transitions may have the following elements:

- **Guard Constraints.** They are conditions which must be true to trigger a transition between two different states. However, if there is an event in the transition, the event must take place and the condition must be true in order for the transition to be triggered.
- **Events**: Events represent noteworthy occurrences that may trigger a transition between states. If there is no condition, the transition will be triggered when the event occurs; otherwise, the condition must also be true when the event takes place. We will distinguish between two types of event:
  - ∗ **Internal Events.** They correspond to conditions stated over the content of the business artifacts or objects, or over time, and may cause the execution of actions without requiring the user's intervention. They are referred to as change or time events in (Olivé, 2007).
  - ∗ **External Events.** They are explicitly requested by the customer of the business process and their behavior is specified by means of a set of associated services. Therefore, *external events are non-atomic*. They roughly correspond to call or signal events in (Olivé, 2007).

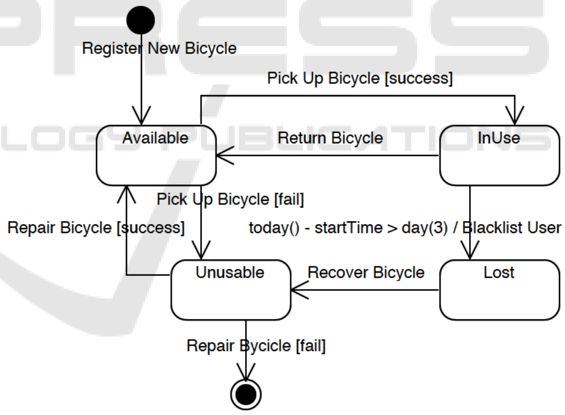


Figure 3: State machine diagram for *Bicycle*.

These events may be accompanied by an **event-dependent condition**. These conditions are placed after the event as they indicate how said event must end in order for the transition to be triggered.

- **Actions.** Actions are automatically executed when the transition fires.

The state machine diagram for the key artifact *Bicycle* in our example is shown in Figure 3. Notice that each subclass of *Bicycle* in the class diagram in Figure 2 now corresponds to a stage in the state machine diagram.

A *Bicycle* is created when it is registered in the system. Initially it is in state *Available*. From the *Available* state, a bicycle may become *InUse*, if a *User* picks it up successfully, or *Unusable*, if he does not (the bicycle may be broken or damaged). Notice that both transitions are triggered by external event *Pick Up Bicycle*, and the final state depends on the event-dependent condition of this event. From state *InUse*, a bicycle will become *Available* again when the user returns it.

When a bicycle is *Unusable*, it needs to be repaired (*Repair Bicycle*) in order to become available again. There are two possible outcomes. If the bicycle is repaired successfully (event-dependent condition *success*) it changes its state to *Available*. If, on the other hand, it is beyond repair, the bicycle is destroyed.

Finally, notice that if a bicycle is not returned for three days after it is picked up (internal event $today() - startTime > day(3)$), action *Blacklist User* is executed and the bicycle changes its state to *Lost*. If at any time the bicycle is recovered (*Recover Bicycle*), then it changes to state *Unusable*, as it will have to be revised and repaired before it can be used again.

We would like to point out that this diagram does not follow exactly the standard described in (ISO, 2012). This is due to the fact that our state machine diagram has event-dependent conditions, which we use to determine whether the event ends successfully or not. In traditional UML state machine diagrams, events are atomic and there is no need for such conditions.

In addition to this, we also allow having more than one outgoing transition from the initial node. This is useful when the artifact can be created in different ways. Alternatively, this situation could be represented using one outgoing transition from the initial node, leading to a state called *InitialState*. From this state, we could have the outgoing transitions that start from the initial node and leave the rest of the state machine diagram as it is. However, representing the lifecycles in this way does not contribute any relevant information and adds complexity to the final diagram.

2.3 Associations as Activity Diagrams

As we have just mentioned, external events and actions in a state machine diagram are non-atomic and consist of a set of services. Consequently, for each external event and action in a state machine diagram we need to specify the services it consists of and the associations between them. Associations in the BALSA framework establish the conditions under which services may execute.

We propose to specify associations using UML activity diagrams as a basis. Therefore, we will define one such diagram for each external event and action in a state machine diagram. Then, for the state machine diagram in Figure 3, we would have an activity diagram for the following external events: *Register New Bicycle*, *Pick Up Bicycle*, *Return Bicycle*, *Repair Bicycle* and *Recover Bicycle*. We would also have an activity diagram for action *Blacklist User*.

The main elements of activity diagrams are the following:

- **Nodes.** We will distinguish between two types of nodes:
  - **Tasks.**[1]: Tasks represent the work that has to be done. In most cases, each task corresponds to a service (as defined in the BALSA framework). However, tasks with a rake-like symbol are further decomposed in another activity diagram. This is particularly useful to reuse certain behaviors. It is the responsibility of the business process modeler to decide how many tasks and services are needed to specify the behavior of an external event or action. Understandability of the diagrams defined is the criterion that should guide this decision.
  - **Control Nodes.** They are used to manage the flow. Examples of control nodes are decision and merge nodes. Decision nodes indicate that only one of the subsequent paths will be taken according to a certain condition. Merge nodes, on the other hand, indicate that the execution of the activity diagram continues after one of its incoming edges carries information. There are other types of control nodes but we will focus on these two.
- **Edges.** Edges connect the nodes among them and establish the order for the execution of the tasks.

In addition to these, we will also use swimlanes, on the one hand, and notes stereotyped as *Participant*, on the other hand. Although not strictly necessary, swimlanes will provide additional information by indicating the main business artifact or object that is involved in each of the tasks and whether the corresponding task deals with material or informational resources. Material tasks deal with physical elements and are represented using stereotype *material* in the swimlane or in the task itself. Informational tasks, on the other hand, deal with the representation of the

[1]Tasks are actually called *actions* in the terminology of UML activity diagrams. However, in order to avoid confusion with actions in state machine diagrams, we will refer to them as tasks throughout this document.

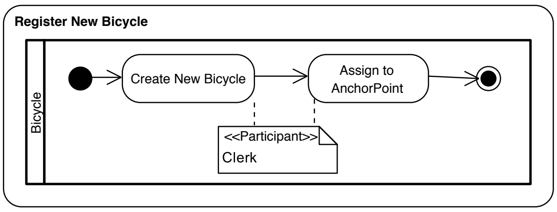


Figure 4: Activity diagram for *Register New Bicycle*.

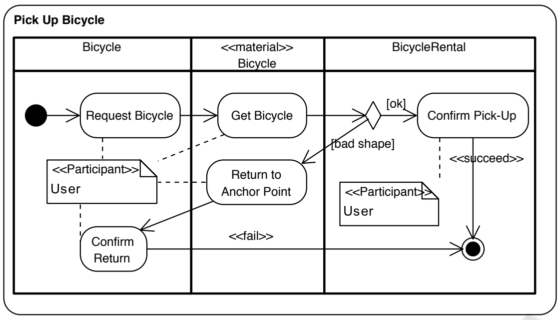


Figure 5: Activity diagram for *Pick Up Bicycle*.

real-life artifact or object. They are shown in the activity diagram as tasks without stereotypes in the swimlane. This distinction is important, because we will only be able to specify services that deal with informational resources and not material ones.

Moreover, we will use notes with stereotype *Participant* to show the role/s of the people who carry out a particular task.

Figure 4 shows the activity diagram of *Register New Bicycle*. First of all, the clerk provides the information of the new bicycle and, after this, he assigns it to an anchor point. The main artifact involved in both services is the *Bicycle*. In this particular case, both tasks are atomic and deal with information and not material resources.

Figure 5 represents the activity diagram of *Pick Up Bicycle*. The user first requests a bicycle to the system and then he physically picks it up from its anchor point. If the bicycle is not in good shape, he returns it to an anchor point and then he confirms the return. Notice that in this case the activity diagram ends in failure. On the other hand, if the bicycle is usable, he takes it with him and confirms the return. Then the activity diagram ends successfully. It is important to make this distinction between success and failure as depending on the result of the activity diagram, the bicycle will change to state *InUse* or *Unusable*, as shown in Figure 3.

In this particular diagram, there are two tasks or services that deal with material resources: *Get Bicycle* and *Return to Anchor Point*, which correspond to physically getting the bicycle from its anchor point and placing it on the anchor point, respectively.

Notice that the approach that we follow to specify associations is *procedural* in the sense that the activity diagrams define a clear order for the execution of services. In contrast, most artifact-centric proposals follow a *declarative* approach where associations define the conditions under which services *may* be executed. Our use of activity diagrams to specify associations brings it closer to process-centric methodologies while keeping its artifact-centric nature.

2.4 Services as Operation Contracts

In the context of the BALSA framework, a service is a unit of work meaningful to the whole business process. Services create, update and delete business artifacts. In turn, this may make artifacts evolve to a new stage meaningful from the business perspective. In our approach, services correspond to the informational and atomic tasks in the activity diagrams.

UML does not have a way to represent services graphically. Instead, they are defined by an operation contract which states what the service does. Operation contracts consist of a set of input parameters and output parameters, a precondition and a postcondition. Both input and output parameters can be classes (i.e. business artifacts or objects) or simple types (e.g. integers, strings, etc.). A precondition states the conditions that must be true before invoking the operation and refers to the values of attributes at the time when the service is called. The postcondition indicates the state of the business artifacts or objects after the execution of the operation. Those artifacts and objects that do not appear in the postcondition keep their state from before the execution of the operation. To avoid redundancies with the integrity constraints of the class diagram we assume a strict interpretation of operation contracts (Queralt and Teniente, 2006).

These operation contracts might be specified by means of different languages, such as natural language. However, the resulting specification would be ambiguous since it would allow for multiple interpretations. Therefore, we propose to specify services using operation contracts defined in OCL. As we have already mentioned, OCL is a formal language that avoids ambiguities. Moreover, it is declarative, which means that it does not indicate *how* things should be done, but rather *what* should be done.

We have shown in Figure 4 that the external event *Register New Bicycle* is performed by means of two services (i.e. tasks): *Create New Bicycle* and *Assign to Anchor Point*, which are informational and atomic. Therefore, we need to specify an operation contract for each such service.

Listing 1: Code for action *CreateNewBicycle*.

```
action CreateNewBicycle (bId: String): Bicycle
localPre: -
localPost:
 Bicycle.allInstances()->exists(b |  b.oclIsNew()
      and b.id=bId and b.oclIsTypeOf(Available)
      and b.inServiceSince = today() and result=b)
```

Listing 1 shows the operation contract of service *Create New Bicycle*. It has as input parameter the *id* of the *Bicycle* that we are adding to the system. The service creates a new bicycle in state *Available* with the given *id*.

Listing 2: Code for action *AssignToAnchorPoint*.

```
action AssignToAnchorPoint (b: Bicycle, apNumber:
     Natural, stationId: String)
localPre: -
localPost:
 b.oclAsType(Available).anchorPoint =
      AnchorPoint().allInstances()->select(ap |
      ap.number=apNumber and
      ap.station.id=stationId)
```

Listing 2 shows the OCL code for *AssignToAnchorPoint*. Given a *Bicycle* and the identifiers of an AnchorPoint (*AnchorPoint number* and *Station id*) as input parameters, it assigns the bicycle to the corresponding *AnchorPoint*. Notice that both the operation contracts in Listings 1 and 2 have no preconditions in order to avoid redundancies. For instance, Listing 2 does not check whether there exists an *AnchorPoint* with the given identifiers.

3 RELATED WORK

This section identifies and examines different alternatives to represent the four dimensions in the BALSA framework. We will mainly focus on artifact-centric approaches, although we will also give an overview of process-centric approaches.

3.1 Artifact-centric Approaches

Although not all researchers who work with artifact-centric business process models specifically use the BALSA framework, it is not difficult to establish a correspondence between their system of representation and the dimensions in the framework. Therefore, in order to facilitate the analysis of the existing alternatives, the subsection has been structured according to these dimensions.

Business Artifacts. Business artifacts, sometimes referred to as business entities, are represented in different ways in the literature. Various authors use database schemas (Bagheri Hariri et al., 2011; Bagheri Hariri et al., 2013; Belardinelli et al., 2011; Cangialosi et al., 2010). A similar representation is proposed in (Bhattacharya et al., 2007b; Damaggio et al., 2012; Fritz et al., 2009; Nigam and Caswell, 2003) where artifacts consist of a set of attributes or variables. Another alternative is to add an ontology represented by means of description logics on top of a relational database (Calvanese et al., 2012). None of these representations is graphical; therefore, this makes them more intricate and more difficult to understand at a glance. For instance, it is complex to see the relationships between the different artifacts.

On the other hand, (Bhattacharya et al., 2009; Fahland et al., 2011; Hull et al., 2011b; Hull et al., 2011a; Damaggio et al., 2013; Lohmann and Wolf, 2010) use different graphical and formal representations for business artifacts. (Lohmann and Wolf, 2010) chooses to represent artifacts as state machine diagrams defined by Petri nets. However, little attention is given to the way the attributes are represented, as the paper is focused on adding the concepts of agent and location to artifact-centric process models. Conversely, (Hull et al., 2011b; Damaggio et al., 2013; Hull et al., 2011a) represent the business artifact and its lifecycle in one model, GSM, that includes the artifact's attributes. The drawback of using GSM is that the relationships between artifacts are not made explicit. Another alternative is using an Entity-Relationship model as it is done in (Bhattacharya et al., 2009). (Fahland et al., 2011) represents the data model of their example by means of an UML class diagram. Both (Fahland et al., 2011; Bhattacharya et al., 2009) use a graphical and formal notation to represent the artifacts' attributes and their relationships, making them easier to understand.

Lifecycles. When it comes to defining the lifecycle of business artifacts, there are two main alternatives: existing approaches either offer an explicit representation of the evolution of the artifact or it is implicit. The lifecycle may be implicitly represented by dynamic constraints expressed in logic (Bagheri Hariri et al., 2011) or the actions that act upon artifacts (Belardinelli et al., 2011; Cangialosi et al., 2010; Bagheri Hariri et al., 2013; Calvanese et al., 2012).

On the other hand, explicit representations are normally based on a state machine diagram. An example is (Bhattacharya et al., 2009). State machine diagrams provide a clear representation of the evolution of an artifact, showing the different stages in its lifecycle and how each stage is reached.

A similar alternative to state machine diagrams is GSM, first described in (Hull et al., 2011b) and further studied and formalized in (Damaggio et al., 2013; Hull et al., 2011a). Like state machine diagrams, GSM allows representing graphically guards and stages. However, it adds the concept of milestone to represent conditions that determine the closing of a state. On the other hand, the sequencing of stages in the lifecycle of the artifact is determined by guard conditions instead of edges connecting the stages, making it much less visual and straighforward. Nevertheless, it is possible to use edges as a *macro*.

Another formal approach is the one used in (Fahland et al., 2011; Lohmann and Wolf, 2010), where lifecycles are represented in variants of Petri nets. A similar alternative is proposed in (Kucukoguz and Su, 2011), where ArtiNets (similar to Petri nets) and DecSerFlow, a declarative language, are used to represent the lifecycle of an artifact and its constraints. These Petri net variants offer an understandable graphical representation that is also formal.

Finally, another possibility is to use a variable in the artifact which stores its state (Damaggio et al., 2012; Bhattacharya et al., 2007b). Although it is an explicit representation, it only shows the current state of the artifact, instead of showing how it will evolve from one stage to the next. Therefore, it is a poorer form of representation in contrast to state machine diagrams, variants of Petri nets or GSM.

Associations. Associations are represented in different ways depending on the approach of the paper. Some authors opt for using condition-action rules defined in logic (Bagheri Hariri et al., 2011; Bagheri Hariri et al., 2013; Cangialosi et al., 2010; Calvanese et al., 2012). (Bhattacharya et al., 2007b) calls these conditions business rules; they should not be confused with business rules in (Damaggio et al., 2012), which are conditions that are superimposed in the already existing ones. In (Damaggio et al., 2012), preconditions determine the execution of the actions; therefore, they act as associations. As in the case of services, associations defined in logic have the advantage of being formal and unambiguous; on the other hand, they will be difficult to understand for the people involved in the business process. In addition to this, the fact that they are not represented in a graphical way makes it more difficult to know, at a glance, the order in which the services will or can be executed.

Likewise, (Bhattacharya et al., 2009) uses event-condition-action rules, but they are defined in natural language. As we have already mentioned, using natural language makes them easier to understand, but they are not formal and may have ambiguities. Moreover, like in the case of associations defined in logic, it is difficult to know, at a glance, the order in which services may be executed, as it is not a graphical representation.

Alternatively, (Fahland et al., 2011) uses what the authors call *channels* to define the connections between *proclets*. A proclet is a labeled Petri net with ports that describes the internal lifecycle of an artifact. Another option is DecSerFlow, that allows specifying restrictions on the sequencing of services, and it is used in (Kucukoguz and Su, 2011). It is a language grounded on temporal logic but also includes a graphical representation. Therefore, both alternatives are graphical and formal.

On the other hand, (Nigam and Caswell, 2003; Bhattacharya et al., 2007a) opt for a graphical representation using flowcharts. The advantage of using flowcharts is that they show, in a graphical and straightforward way, the order in which services will be executed, making them easy to understand. However, they do not use a particular language to define the flow and little attention is given to the way of creating the flowchart.

Services. Services are also referred to as tasks or actions in the literature. Despite the different terminology, in general they are described by using pre and postconditions (also called effects). Different variants of logic are used in (Bagheri Hariri et al., 2011; Bagheri Hariri et al., 2013; Damaggio et al., 2012; Bhattacharya et al., 2007b; Fritz et al., 2009; Belardinelli et al., 2011; Calvanese et al., 2012) for this purpose. The same idea is followed in (Cangialosi et al., 2010; Damaggio et al., 2013) but omitting the preconditions. Using logic means that the definition of services is precise, formal and unambiguous, but it has the problem of being difficult to understand for the people involved in the process.

Conversely, (Bhattacharya et al., 2009) uses natural language to specify pre and postconditions. In contrast to logic, natural language is easy to understand, but it is an informal description of services: this implies that the service definition may be ambiguous and error-prone.

3.2 Process-centric Approaches

It is precisely because process-centric approaches focus on the order of the activities that have to be carried out, that most alternatives only represent one of the elements of the BALSA framework, the associations. As (Weske, 2007) shows, there are many different languages to represent business processes from a process-centric perspective such as BPMN, UML activity diagrams, Workflow nets or YAWL. Although some of these languages have the ability to represent the data needed in the flow (even if in a limited way), process-centric proposals focus on the ordering of the activities or tasks and do not deal with the data.

However, in some cases they do take data into consideration. For instance, (Trcka et al., 2009) represents the associations between services in a WFD-net (WorkFlow nets annotated with Data). The annotation of tasks in the WFD-Net can be seen as a rudimentary way of specifying services, as it allows indicating which data is created, read and written. Similarly, (Ly et al., 2006) uses WSM nets which represent both the control flow and the data flow, although the data flow is limited to read and write dependencies between activities and data. In like manner, (Liu et al., 2007) represents associations in an operational model, which shows tasks (or services) as nodes connected using arrows or edges. The operational model also shows the transfer of artifacts between tasks by indicating them over the edges. However, details of artifacts are not shown.

3.3 Summary of Related Work

As we have seen, none of the approaches that we have analyzed uses the same language to represent all the elements in the BALSA framework, and many times the chosen representation is not graphical, making the models more difficult to grasp. This is aggravated by the fact that, in some cases, the chosen language is a variant of logic which, although formal, makes it next to impossible for business people to comprehend. The use of natural language also has its drawbacks: while it may be easily understood, it may lead to ambiguities and errors.

4 CONCLUSIONS

This paper shows a way to model all of the BALSA dimensions in an artifact-centric business process model using several diagrams based on UML. The use of an activity diagram to represent the associations between services brings it closer to process-centric methodologies and makes it easier to understand than condition-action rules defined in logic or even natural language.

In contrast to other approaches, using diagrams based on UML and OCL as a basis to represent *all* of the dimensions of the model integrates them naturally. Moreover, UML has several advantages: first of all, it is a graphical, high-level language, and therefore the resulting models are easy to understand by business managers, analysts and developers. Secondly, UML and OCL are standard languages. Last but not least, both UML and OCL can be translated into logic (see for instance (Queralt and Teniente, 2012)) in order to facilitate reasoning on the resulting specification.

Finally, our proposal offers the advantages of a graphical representation, understandable by the users, without losing the capacity of being used for reasoning in the future since it is based on a semi-formal notation that avoids ambiguities. As further work, we would like to study the applicability of our approach by analyzing the input provided by the business stakeholders. We would also like to apply this work to a business process model which has more than one business artifact. Last but not least, we intend to define a way to perform automatic reasoning on our diagrams in order to validate their correctness, appropriateness and their quality before they are put into practice.

ACKNOWLEDGEMENTS

This work has been partially supported by the Ministerio de Ciencia e Innovación under projects TIN2011-24747 and TIN2008-00444, Grupo Consolidado, the FEDER funds and Universitat Politècnica de Catalunya.

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