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Assessing Aspect Oriented Approaches in Business Process Management

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Abstract. Separation of concerns is an important topic in Business Process Modeling. One sort of concerns is cross-cutting, like security, which are repeated in many business processes. These concerns make the models more complex, since concerns are repeated in many process models. The repetition of realization of concerns in process models makes the maintenance cumbersome. Aspect Oriented Business Process Modeling is an approach to address these concerns, which has been investigated recently. However, no set of requirements are defined for such modeling proposals, which makes the evaluation of and comparison between these approaches impossible. Therefore, this paper introduces a set of requirements for the aspect oriented business process modeling, which are used to define an evaluation framework for assessing these modeling approaches. The framework is used to evaluate existing aspect oriented business process modeling proposals. The result shows a comparison between different modeling proposals by clarifying their strengths and weaknesses. It also shows the gap in the area, which can be used as direction for future research.

Keywords: Business Process Modelling, Aspect Oriented, Requirements, Evaluation

1 Introduction

Business Process Modeling is an important area, aims to enhance the (re-)design of business processes to be more efficient. Processes can be very complex, which makes the process models complex as well. This complexity hinders the comprehension of process models, so different techniques are used in process modeling to deal with the complexity like separation of concerns. By separating concerns, people can deal with less complex modules at a time, which enhance their capability to understand the process models. This ability empowers people to re-design processes to improve efficiency.

Process models contain different concerns, which can be separated through three modularization techniques such as vertical, horizontal and orthogonal [11]. *Vertical Modularization* aims to hide process details by introducing sub-processes, which improves the modeling structure of a process for dealing with complexity. The domain of a sub-process is limited to one process, and it can be re-used

several times in the process. *Horizontal Modularization* aims to facilitate dealing with the complexity of process models by introducing peer modules. These modules can be considered as sub-processes, which are common for different process models and are not limited to one process. In this way, a peer module can be re-used in different processes. *Orthogonal Modularization* aims to separate the dependency of process models from peer modules, so the relation between peer modules and process models would be documented using some rules. In this way, the usage of peer modules can be altered by changing the rules, rather than updating all process models. These techniques can be used to separate different types of concerns.

Different techniques are introduced for modeling different sort of concerns, among which Aspect Oriented Business Process Modeling aims to separate cross-cutting concerns from process models. Cross-cutting concerns are those which their realization in process models results in scattering and tangling problem. *Scattering* means that the realization of concerns should be repeated in different process models, e.g. different process models should comply to one security concern. *Tangling* means that the changes in application of the concern need to be reflected in different process models, e.g. if the security concern does not need to be applied for the payment, all processes which have payment mechanism should be found and untangled. Aspect oriented business process modeling aims to separate both realizations of these concerns and their application, which improves re-usability, maintenance, and dealing with complexity [2, 4, 8].

Although different modeling approaches are proposed for aspect oriented business process modeling, there is not any comprehensive definition of requirements to specify the characteristics that these models should have. This gap hinders the evolution of this sort of modeling, since it is not possible to consider the missing parts in proposed approaches. Moreover, it is not possible to compare these approaches with each other to investigate which one has a better degree of support for separation of cross-cutting concerns.

Therefore, this paper defines a set of requirements for Aspect Oriented Business Process Modeling. It defines a framework based on these requirements that can be used for evaluating this kind of modeling approaches. It also evaluates existing aspect oriented business process modeling approaches and shows the pros and cons of each approach. The result of this evaluation shows the missing areas which require more research and further investigation.

Thus, the paper is organized as follows. Section 2 introduces the basic modeling structures which are needed for Aspect Oriented Modeling. Section 3 defines a set of requirements for aspect oriented business process modeling, which should be considered when defining a modeling notation. These requirements are used to construct a framework for evaluating the aspect oriented business process modeling approaches in section 4. In section 5, an evaluation of ten existing modeling approaches is given. Finally, section 6 concludes the paper and introduces the direction for future works.

2 Background

This section introduces basic constructs of Aspect Oriented Business Process Modeling through an example. These constructs are common in aspect oriented approaches in different disciplines such as programming [10], which are aimed to solve scattering and tangling problem in Business Process Management (BPM) by enable separation of cross-cutting concerns from process models. Fig. 1 represents a motivating example which is used in this section to facilitate depiction of the problem and its solution.

The example in Fig. 1 contains two sides: the left side of the figure shows the relation between cross-cutting concerns and some process models; the right side of the figure shows a fictitious process model, called **Transfer Money Process**. As it can be seen on the left-hand side, a concern can be repeated in many process models, which result in scattering problem. The process on the right side of the figure starts when a customer fills a form. If the customer wills to transfer money to his or her account, no security control is taken. Otherwise, the customer should sign the transaction, and the request is investigated for potential fraud detection. Afterwards, the money is transferred. As a part of security concern, the customer will be notified about the transaction if the destination account is owned by another person. Finally, the transaction should be logged. This process is tangled to logging and security concerns, which means that the activities which are needed to represent the process model is twisted with concerns' activities.

The scattering and tangling problems result in many difficulties in designing and maintaining business processes. For example, if the security aspect is changed in this example, all processes should be examined to consider if they should be also altered. This can result in inconsistency between processes and different aspects, if a realization of an aspect is forgotten to be updated in one process model. In this way, managing changes in cross-cutting concerns are cumbersome and hinders supporting modeling and enactment of business processes. The aspect orientation aims to solve the scattering and tangling problem.

To solve the scattering and tangling problems, both cross-cutting concerns and their dependencies to process models should be separated from process definition. Therefore, orthogonal medialization can be applied to solve this problem through encapsulating cross-cutting concerns and the dependency rules into separated modules. In this way, cross-cutting concerns and their dependencies can be changed without hindering process model's definitions.

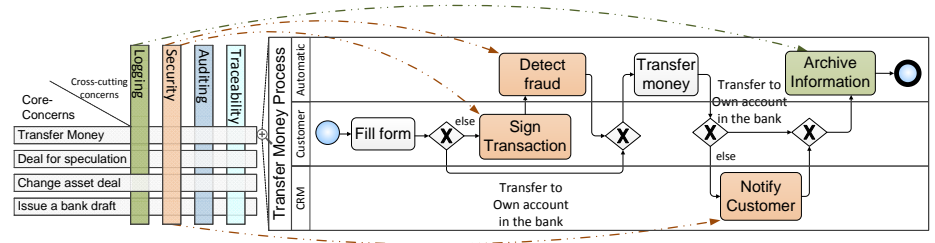


Fig. 1. Cross-cutting concerns in Transfer Money Process

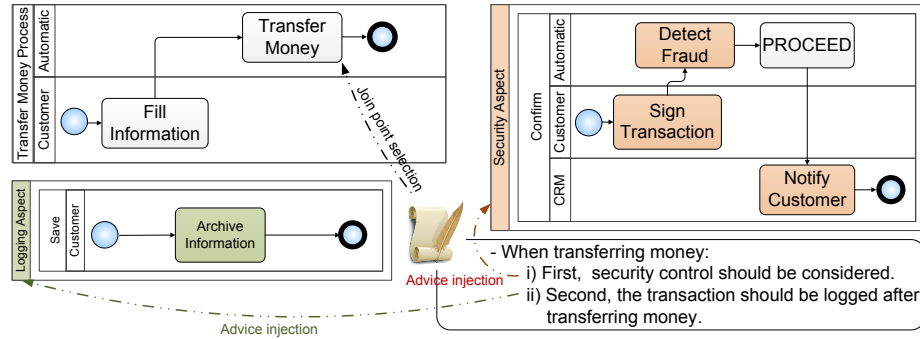


Fig. 2. Aspect Oriented Modeling in BPM

Cross-cutting concerns can be separated through encapsulating them into individual peer modules, called advices. An *advice* is a process model which has a start and an end event. It also contains activities, which must be performed for realizing a cross-cutting concern. Fig. 2 shows an aspect oriented model for the given motivating example, where **Confirm** and **Save** processes represent the realization of a security and logging cross-cutting concerns respectively. A set of advices with a common goal can be grouped together in a module called *aspect*. In this example, **Confirm** advice belongs to **Security Aspect** and **Save** advice belongs to **Logging Aspect**.

The dependency between cross-cutting concerns and process models can be separated through definition of rules, called *Pointcuts*. Each pointcut specifies rules, which indicate points in process models for them an advice should be applied. The potential points in process models that a pointcut can select is called *join points*. These points are activities in a process model, e.g. **Fill Information** and **Transfer Money** activities in Fig. 2. The point which is selected by a pointcut is called *advised join point*, and the selection process is called *join point selection*. For example, **Transfer Money** activity is selected by the defined pointcut in Fig. 2. An advice can be considered before, after or around an advised join point [4]. To enable the around scenario, the place of the advised join point can be defined using a placeholder in the advice process, called **PROCEED** (see **Confirm** advice in Fig. 2).

Each pointcut can also define the relation between cross-cutting concerns for a specific point in a process model. Advices can have the same order or different orders [8]; for example, the security concern in Fig. 2 should be considered before the logging concern. This information can be specified in pointcut definition. Through this definition, pointcut specifies how different advices should be related to advised join points. This process is called *advice injection*.

There are different aspect oriented business process modeling approaches, which are defined based on this set of requirements. Although they mostly support definition of these elements, their capability in supporting separation of cross-cutting concerns are different. The difference is rooted in the set of requirements that they support. To evaluate their separation level and enable

comparison between them, next section introduces sets of requirements for aspect oriented business process modeling.

3 Requirements

This section introduces a set of requirements that an aspect oriented business process modeling should fulfill to enable supporting cross-cutting concerns in BPM area. The requirements are compiled through literature review, and lesson learned from case studies by enabling aspect orientation [8, 7, 9]. Two sets of requirements are defined. The first set is compulsory without them aspect oriented business process modeling cannot be enabled in BPM. The second sets are optional, which enable assessing the level of separation of cross-cutting concerns from process model for each approach.

3.1 Basic Requirements (B.R.)

Four important perspectives are recognized in BPM area to specify a business process, i.e. functional, control-flow, data and resource perspectives. Functional perspective describes the activities that a process contains. Control-flow perspective specifies the order between these activities. Data perspective indicates the required information to perform an activity. Resource perspective describes the resource (person or system) that should perform the activity. An aspect oriented business process modeling aims to extend the functionality of process modeling to support separation of cross-cutting concerns. Thus, it should support these perspectives as well. Moreover, cross-cutting concerns can be separated if the solution addresses the scattering and tangling problem, so it is a basic requirement for every Aspect Oriented Business Process Modeling approach to address scattering and tangling problem. Therefore, three basic requirements can be defined for every Aspect oriented Business Process Modeling approach such as:

- B.R.1. Aspect Oriented Business Process Modeling should support definition of business processes using functional, control-flow, data and resource perspectives.
- B.R.2. Aspect Oriented Business Process Modeling should remove scattering problem in definition of concerns in process models.
- B.R.3. Aspect Oriented Business Process Modeling should remove tangling problem in definition of concerns in process models.

3.2 Measurement Requirements (M.R.)

The requirements for assessing the maturity of an aspect oriented business process modeling approach can be defined based on three issues: i) the strongness of join point selection, ii) the strongness of advice injection and iii) the available support for different phases in BPM lifecycle. The join point section depends

on two sub-issues, i.e. *Signature Exposure* and *Rule Composition*. The advice injection depends on two sub-issues, i.e. *Pointcut Definitions* and *Transformation Patterns*. These issues and their requirements are explained below.

Signature Exposure (M.R.S.) The first step in join point selection is recognizing the points in process models to which an advice can be related. These points can be exposed by process models based on different business process perspective, i.e. functional, control-flow, data and resource. The points which can reveal information about each of these perspectives are called signatures. This term is borrowed from Aspect Oriented Programming paradigm [10]. There are four types of signature that can be defined in aspect oriented business process modeling:

- *M.R.S.1 Process: the approach should expose points of control-flow perspective of processes for which a concern can be defined.* The process name can be considered as an exposure point, which enables the definition of the relation between cross-cutting concerns to a process model.
- *M.R.S.2 Tasks: the approach should expose points for functional perspective for which a concern can be defined.* For example, the names of activities are candidates for task signatures.
- *M.R.S.3 Data: the approach should expose points for data perspective for which a concern can be defined.* For example, reading and writing a data entity can be defined as data signatures in process models.
- *M.R.S.4 Resource: the approach should expose points for resource perspective for which a concern can be defined.* For example, the resource name and role can be considered as resource signatures.

Rule Composition (M.R.R.) The join point selection is derived through interpreting pointcut rules when an instance of a process model is enacted, and the rules play an important role in enabling separation of cross-cutting concerns. The rules can be defined using information about different perspectives of a process model. The degree of separation is related to the number of perspectives that can be used in composing rules. Moreover, it is important if a pointcut can be defined based on a composition of different perspectives' information, and if there is a dominant perspective in composition of rules. A dominant perspective is a perspective that all other perspectives should be defined based on it. For example, functional perspective is considered as a dominant perspective in rule composition in AO4BPMN [4]. The existence of a dominant perspective result in definition of rule redundancy [7]. Therefore, the following requirements can be considered to evaluate the rule composition dimension.

- *M.R.R.1 Process: the approach should support definition of rules based on control-flow perspective information.*
- *M.R.R.2 Task: the approach should support definition of rules based on functional perspective information.*
- *M.R.R.3 Data: the approach should support definition of rules based on data perspective information.*

- *M.R.R.4 Resource: the approach should support definition of rules based on resource perspective information.*
- *M.R.R.5 Combination: the approach should support composition of rules based on combinations of different process perspectives.*
- *M.R.R.6 Domination: the approach should support composition of rules without any dominant perspective.* For example, it should be possible to define a rule based on resource perspective information without mentioning the task information.

Advice Relations (M.R.A.) The level of separation is also affected by the ability to define a relation between an advice and i) different join points, and ii) other advices. An advice can be defined to be considered before, after or around a point in a process model. Moreover, an advice can be defined in parallel with other advices, or it can be defined for another advice (nested scenario). It is also possible to have precedence between advices when they are related to a point in a process model.

- *M.R.A.1 Before: the approach should enable definition of before advices.* Before advices are those which are considered before a join point.
- *M.R.A.2 After: the approach should enable definition of after advices.* After advices are those which are considered after a join point.
- *M.R.A.3 Around: the approach should enable definition of around advices.* Around advices are those which are considered around a join point.
- *M.R.A.4 Parallel: the approach should enable definition of parallel advices for a join point.*
- *M.R.A.5 Nested: the approach should enable definition of nested advices.* Nested advices are those which are defined for another advice.
- *M.R.A.6 Precedence: the approach should enable definition of precedence between advices for a join point.*

Transformation Patterns (M.R.T.) In aspect oriented business process modeling, every concern is encapsulated into individual modules. Although this approach makes coping with the complexity easier, it needs transforming knowledge from one module to another. The knowledge can be related to different perspectives, which can be articulated as transformation's patterns. The more pattern supported by an approach means better support for separation of cross-cutting concerns.

- *M.R.T.1 Process: the approach should enable transformation of process level data among different related modules.*
- *M.R.T.2 Task: the approach should enable synchronization of PROCEED placeholders in advices with advised join point.*
- *M.R.T.3 Data: the approach should enable transformation of data among different related modules.*
- *M.R.T.4 Resource: the approach should enable transformation of resources which has performed activities among different related modules.*

Phases Support (M.R.P.) It is important that this modularization technique can be supported in different BPM lifecycle such as design, run and adjustment. The adjustment should be performed for running process instances, and different sort of adjustments can be defined based on the fact that whether the core-functionalities of the business process and cross-cutting concerns are already started at the time of adjustment or not. Therefore, three kinds of adjustment can be defined (see Fig. 3):

- *Backward Adjustment* in which cross-cutting concerns should be adjusted when both the core-functionalities of process model and cross-cutting concerns are enacting. For example, changing the security concern when a purchase process and its related security concern are running.
- *Backward-Forward Adjustment* in which cross-cutting concerns should be adjusted when the core-functionalities of a process model is running, but the cross-cutting concerns realizations are not. This scenario happens when the advised join point in aspect oriented process model is not yet enabled. For example, changing a security concern when a purchase process is running, but its security concerns have not yet run.
- *Forward Adjustment* in which cross-cutting concerns should be adjusted when neither the core-functionality of process model nor cross-cutting concerns realizations are enacting. For example, changing a security concern when a purchase process is not yet started.

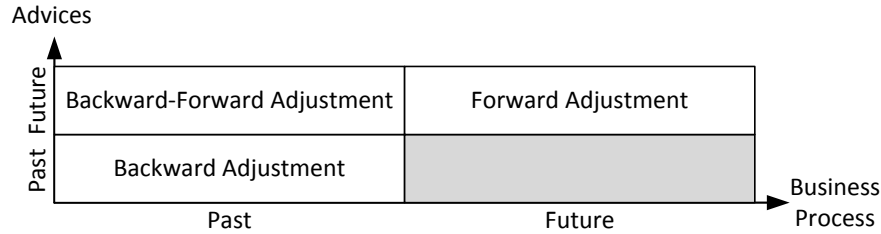


Fig. 3. Adjustment Types

It should be noted that it is not possible to have a scenario in which a cross-cutting concern is running while its business process has not yet started, so the related section is grayed out in the figure. Therefore, the Phases support requirements can be defined as below.

- *M.R.P.1 Design: the approach should support the design of aspect oriented business process modeling.*
- *M.R.P.2 Run: the approach should support enactment of aspect oriented business process models.*
- *M.R.P.3 Backward Adjustment: the approach should support adjustment of running advices.*
- *M.R.P.4 Backward-Forward Adjustment: the approach should support adjustment of new advices for running cases.*

- *M.R.P.5 Forward Adjustment: the approach should support adjustment of advices for new cases.*

4 Evaluation Framework

This section proposes a framework based on defined requirements. This framework can be used for evaluating Aspect Oriented Business Process Modeling approaches. The evaluation contains two steps as mentioned in previous section, i.e. selection and measurement.

In selection step, the approach is evaluated based on basic requirements (B.R.1-B.R.3), i.e. it should enable definition of business processes using control-flow, functional, data and resource perspectives, and it should also address the problem of scattering and tangling of cross-cutting concerns in process models.

To evaluate each approach based on defined measurement requirements,

- Let $M.R.m$ denotes a set of Measurement Requirements, where m is a variable referring to the sub-issues introduces in section 3.2.
 - It means that $M.R.m$ is a set of Measurement Requirements including $M.R.S.$ (Signature Exposure), $M.R.R.$ (Rule Composition), $M.R.A.$ (Advice Relations), $M.R.T.$ (Transformation Patterns) and $M.R.P.$ (Phases Support).
- Let $M.R.m.i$ denotes the i th requirement in $M.R.m$, where i is an integer and $1 \leq i \leq |M.R.m|$
- Let $E.R.m$ denotes Evaluation of Requirements, where m is a variable referring to the specific Measurement Requirement set, i.e. $M.R.m$.

The $E.R.m$ can be calculated using this formula:

$$E.R.m = \left(\frac{(\sum_{i=1}^n M.R.m.i) \times 4}{|M.R.m|} \right) \quad (1)$$

The result can be illustrated using a pentagon containing five dimensions each of which represents a set if of requirements (see Figure 4). The next section shows the evaluation of current approaches in aspect oriented business process modeling using this framework.

5 Evaluation Results

This section shows the evaluation result of applying the framework on different aspect oriented business process modeling approaches. The approaches are selected as a result of studying different literature about aspect orientation in BPM area. The evaluation of approaches contains two steps as mentioned in previous section, i.e. selection and measurement.

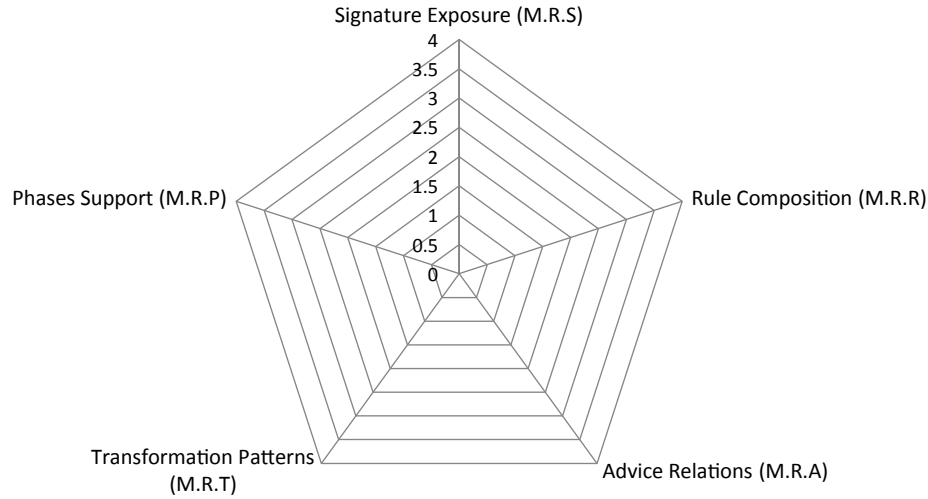


Fig. 4. The illustration for Evaluation Framework result

5.1 Selection Step result

In selection step, ten aspect oriented business process modeling approaches are identified through studying literature. These approaches are evaluated based on basic requirements. The result is shown in Fig. 5. As it can be seen in the figure, half of these approaches do not meet the basic requirements, where:

- The approach proposed by Charfi et al. (AO4BPEL) [3] does not meet the B.R.1, i.e. it does not consider the support for resource perspective.
- The approach proposed by Wang et al. [15] neither meet B.R.1 nor B.R.3, i.e. it does not consider the support for resource perspective, and it relates the process models to cross-cutting concerns through some elements (called lose and gain), which introduces the tangling problem.
- The approach proposed by Shankardass [14], Jalali et al. (AOBPMN) [8] and Collell [5] do not meet the B.R.3 since they introduce elements in the main process model, which introduces the tangling problem.
 - Shankardass [14] introduces dot points in process models as a means to relate processes to cross-cutting concerns.
 - Jalali et al. (AOBPMN) [8] and Collell [5] introduce intermediate conditional events as a way to related process models to cross-cutting concerns.

The other five approaches meet the basic requirements, so they can be assessed using the proposed framework which is explained in the next section.

5.2 Measurement Step result

In this section, each of five approaches which met the basic requirements are assessed. The results are explained below.

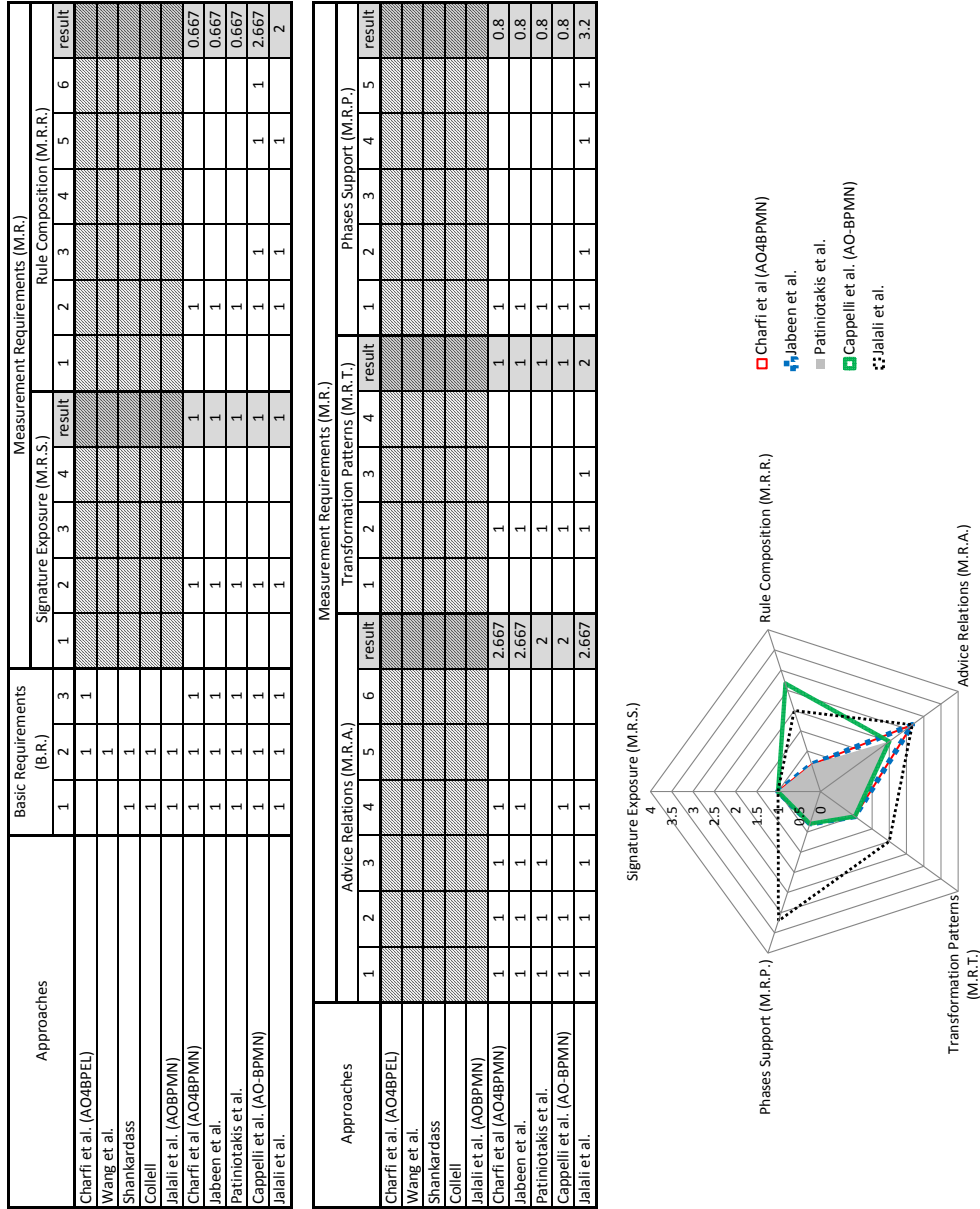


Fig. 5. EvaluationResult

1. Charfi et al. (AO4BPMN) [4] extended Business Process Model and Notation (BPMN) [12] to support separation of cross-cutting concerns from process models. This approach only considers the task signature when defining join points, so it only meets one of the requirements in the Signature Exposure (M.R.S.) set. In rule composition, it simply defines the composition of rules based on task names. Although the authors are aware of other elements, which can be considered in rule definition, they just realize the task information in the Rule Composition (M.R.R.) set for simplicity. AO4BPMN meets four requirements from the Advice Relations (M.R.A.) set, i.e. before, after, around relations between advices and process models. It also supports definition of parallel advices. However, it neither defines the nested relation nor the precedence between advices. This approach only defines how tasks between process models and advices are related to each other, so it merely considers the task transformation pattern from the set of Transformation Patterns (M.R.T.). It also only supports the design phase of BPM lifecycle which meets just one of the requirements from the Phases Support (M.R.P.) set.
2. Jabeen et al. [6] propose an approach based on AO4BPMN in which a concrete language is defined for expressing pointcuts. However, they did not consider any additional requirements when composing rules, which makes the support level of separation of cross-cutting concerns for this approach equivalent to AO4BPMN. Thus, the graph of both this approach and AO4BPMN is identically the same, as it can be seen in Fig. 5.
3. Patiniotakis et al. [13] try to extend AO4BPMN with introduction of some new elements like replace and bypass relation between advices and process models. They did not make it clear if there it is possible to define parallel advices for a join point, i.e. M.R.A.4 requirement. If we assume that they support parallel advice, there will be inconsistency in the approach when an advice wants to replace the join point, and another advice tries to bypass it at the same time. Thus, we have to assume that the authors did not consider this requirement, which result in lower degree of support for separation of cross-cutting concerns from process models in comparison to AO4BPMN (see Fig. 5 where this approach is a sub-set of the AO4BPMN).
4. Cappelli et al. [2] propose an extension to BPMN to support aspect oriented business process modeling. This approach has the same degree of separation as AOBPMN in Signature Exposure, Transformation Patterns, and Phases Support. It has the best degree of separation in Rule Composition dimension as it can be seen in Fig. 5, since it can support rule composition without considering dominant perspective, i.e. M.R.R.6. For evaluating the Advice Relations, it is not clear if this approach support around scenario or not. There is no clue about whether this scenario can be defined in this approach. Moreover, it is not clear if this approach support nested advices and precedence between advices. Therefore, this paper assumes that these requirements are not supported. Thus, this approach is not strong in defining Advice Relations.

5. Jalali et al. [9] propose an approach to support aspect oriented business process management in Yet Another Workflow Language (YAWL). The approach only supports task signature exposure like other approaches. However, it enables composition of pointcut rules based on both task and data perspectives and their combinations. At the same time, it considers task perspective as the dominant dimensions when composing rules. Therefore, it supports a better degree of separation in terms of rule composition in comparison with Charfi et al. [4], Jabeen et al. [6] and Patiniotakis et al. [13], but it is weaker than Cappelli et al. [2] in rule composition. This comparison can be clearly seen in Fig. 5 where Cappelli et al. [2] approach has a higher degree in Rule Composition. This approach also supports the same degree of advice relations like AOBPMN. However, it is a little better in Transformation Patterns since it supports data transformation between process instances and advices. Finally, it has the best degree for supporting separation of cross-cutting concerns in phases support, where it supports design, run, backward-forward adjustment and forward adjustment.

6 Conclusion and Future Works

This paper proposes an assessment framework for evaluating aspect oriented business process modeling approaches for the first time. The framework measures different approaches based on five dimensions, which are defined for evaluating the degree of separation of cross-cutting concerns from process models. Each dimension defines a set of requirements, which are required for aspect oriented business process modeling. The requirements are defined through studying literatures and by lessons, which have been learned through enacting aspect oriented business process models in case studies. The framework is applied for current approaches, and the result shows the strength and weakness of each approach. It also enables comparison between different approaches to understand which one supports better degree of separation of cross-cutting concerns from process models. It also makes the gaps in this area clear, which resulted in discovering directions for prospective works in aspect oriented business process modeling. The future works can be defined in five identified categories:

- **Signature Exposure:**
 - How the process signature can be defined in aspect oriented business process modeling. This investigation can enable definition of aspects like a security concern which must be performed before starting the purchase process.
 - How the data signature can be defined in aspect oriented business process modeling. This investigation can enable definition of aspects for data elements. For example, a security concern which must be performed when a customer account balance is going to be changed.
 - How the resource signature can be defined in aspect oriented business process modeling. This investigation can enable definition of aspects for resource elements. For example, a security concern when some special people in organization want to perform a task.

- **Rule Composition:**
 - How process data can be used when composing rules. The use of process data in rule composition can support better degree of separation. For example, many complex scenarios can be addressed such as having a security mechanism if the account balance which is changed by a task exceeds some limits in comparison with the process level data.
 - How resource data can be used in composing rules. This is a very important aspect, since it enables the definition of many other aspects like if resources are busy, request for additional resource. The aspect oriented business process modeling can support many complex scenarios by supporting resource perspective in composition of rules.
- **Advice Relations:**
 - How nested advice can be modeled is also an important issue to be investigated. This investigation enables capturing more real cases such as a logging concern for a security concern.
 - How precedence should be supported is an important issue that is also investigated by Jalali et al. [8]. This requirement is critical since cross-cutting concerns do not always have the same order.
- **Transformation Patterns:**
 - It is important to investigate how to transform process data between main processes and cross-cutting concerns and vice versa. This mechanism enables transformation of knowledge between the main process and its related advices.
 - It is also important to investigate how resource information should be transferred between different process instances, for example, between the main process and its advices. This investigation enables enforcement of different resource patterns in aspect oriented business process modeling like four-eye principle, segregation of duties, binding of duties, conflict of interest and need-to-know scenarios [1].
- **Phases Support:**
 - The approach proposed by Jalali et al. [9] already supports most of the phases support requirements except backward adjustment. Thus, it is important to investigate how cross-cutting concerns can be adjusted while their instances are running.

Furthermore, the combinations of these requirements can be considered as directions for future research, since the full degree of separation cannot be addressed while all the requirements are not fulfilled. The framework can also be extended to cover more requirements. Moreover, it can inspire to define evaluation frameworks for other aspect oriented approaches in other disciplines like programming.

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