Adaptive Business Process Visualization for a Data and Constraint-Based Workflow Approach

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Abstract. This paper introduces a novel approach which unifies a data-centric and a constraint-based workflow principle. This unified approach offers a scalable flexibility during the process execution and supports the requirements of knowledge intensive business processes. By the integration of a knowledge-based system, process definition and execution relevant data coincide on an ontology-based semantic net. The data, mainly driving the process, can be delivered by different sources or can be the result of an inference step by the underlying ontology. In such a case, AI technology plays an active role during the execution of processes and results in a division of labor with human actors. Such an AI contribution in the process execution must be presented explainable to the user and for a common understanding, this paper presents a concept for a business process visualization adapted to the introduced unified approach. Established strategies for the adaptation of process views are under examination and new strategies will be presented to utilize the integrated knowledge-based system for a semantic oriented process visualization.

1 Introduction

In today's business, Process-Aware Information Systems [1] play an essential role for many companies. Often, these companies have to manage a large number of processes, involving different organizational units, a large number of human actors, and a multitude of activities. On the management and controlling level, users want to be informed about status and progress of such processes with a different granularity depending on their departmental focus. On the contrary, the participating user must execute certain process steps, where each of which requires that specific data or knowledge is available.

In many applications, a process is presented more or less in the same way as it was designed by the process designer. This usually does not fit to the specific needs of a user for the execution of an activity. Previous research has addressed these aspects [3, 9, 16] and have developed different concepts and approaches for business process visualizations (BPV).

Current BPV approaches are developed for an activity-centric (usually imperative) workflow principle where the activities are directly related to each other and form a control-flow or constraints define some rules for their execution. However, with view to the demand of knowledge intensive processes for

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flexibility at design- and run-time [7], new concepts based on data-centric approaches are subject of investigation and have formed an active field of research [14, 2, 4] over the last decade. These approaches have in common that the activities are no longer directly related to each other. Instead, the activities are bound to the data elements which are required to perform an activity (input) or which are the result of it (output).

Such data-centric approaches come along with characteristics, fitting very well to an ontology based data management and form the preconditions for further intelligent process contributions. In this way, the process data can be used to create new information by simple inference mechanisms, exploiting the accessible knowledge. Moreover, the semantic description of the relations between data and activities can be utilized for a sophisticated process visualization as it will be shown within this paper.

We do not only consider process visualization as a possibility, but as well as a requirement. As soon as AI techniques play an active role in the execution of a process, the division of labor with human actors requires a common understanding of the process subjects. The business process visualization is the connector in this human-machine communication.

In the following we present a BPV approach based on a knowledge-based system. Therefore, section 2 introduces the elementary workflow principles. Additionally, the state of business process visualization concepts is presented. Section 3 motivates the model for a unified approach for business process modeling and execution. The capabilities are explained in detail by using an example. Section 4 introduces a new concept of a semantically oriented BPV for the unified workflow approach. Our motivation is expressed and the requirements, the architecture as well as view adaptation methods are presented. We conclude our paper by giving an outlook on our future research in Section 5.

2 Foundations

In the following, we briefly summarize relevant previous research related to business process modeling, execution, and visualization.

2.1 Business Process Modelling and Execution

Business Process Model and Notation (BPMN) is up-to-date the de facto standard for designing and describing business processes world-wide. In the center of this approach reigns a control-flow coordination of process-steps (activities). A less restrictive, but still activity-centric perspective is supported by constraint-based approaches [15], which allow flexibility in a scalable manner. Alternatively, there are several approaches with the intention to gain flexibility based on the control-flow principles [17, 13]. Despite of the consideration of data-flow in such processes, the data is just integrated in a kind of an afterthought [6, 4]. Opposed to this, knowledge intensive processes are usually barely structured and the execution is driven by user decisions and business data. Previous research has shown [19, 2, 14] that an activity-centric perspective is not sufficient to achieve such knowledge intensive business goals.

With view to these insights, several new approaches were brought up during the last decade, putting the data into the center, not only for the design but also for the execution phase of the processes. The case handling paradigm [19] elevated the result of a process (case), reflected by its data objects; activities do not longer drive the process but serve the outcome. For more complex scenarios with the need of abstraction capabilities, object-awareness approaches refined the case handling concept[20]. With business artefacts [2], CorePro [14], and PHILharmonicFlows [11] there are even more approaches to mention which underline the importance of data-centric approaches for knowledge intensive business goals.

The existing workflow principles can be differentiated regarding the rationale for selecting activities for execution. Under a control-flow, the activities are chosen for the execution primarily by the connected ancestors, while a constraint-based model selects the activities by considering a set of restrictions. Both principles put the activity into the center of the view. This changes with the data-centric approaches, where activities are executable as soon as the necessary information is available and the expected outcome on a new information is still required for further process activities. This is expressed by the taxonomy of workflow principles, shown in Fig. 1.

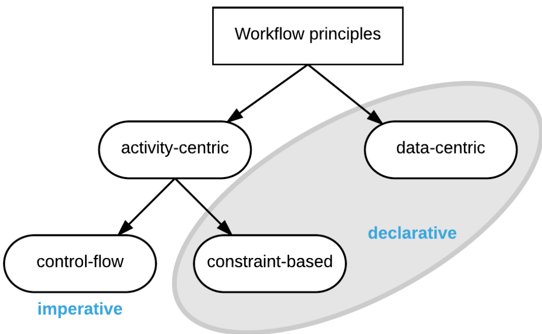

Fig. 1. Workflow principles

The data-centric as well as the constraint-based concepts have in common that in both cases the relations between objects are described, while the execution order is deduced on the fly. This represents a declarative workflow definition, while the control-flow explicitly describes the execution order showing its imperative character.

The nature of both declarative principles is their inherent flexibility. Nonetheless there are major differences. With a data-centric approach, possibilities for the execution of activities are described, which support the requirements of knowledge intensive processes [7]. In contrast to this, constraints define the restrictions between activities, building the foundation for controlling and observing compliance rules. In a nutshell, data-centric principle defines the GO's, while constraints are beneficial to describe the NO-GO's. In this paper, we argue that both principles can be combined to build a unified approach, since both base on a declarative paradigm. This new approach will be introduced in section 3.

2.2 Visualization

The importance of visualization within all fields with a human-computer interaction is well established [5] and is subject to research in many segments. This paper considers mainly the field of business process visualization [3, 18, 10] (in the following denoted BPV).

The most established toolset to model business processes (BPMN) comes along with a detailed graphical notation definition. Graphs are built during the modeling phase and are usually used directly, when it comes to a process visualization later on. It represents the perspective of a process designer, which in general does not fit to the demands and needs of a process controller or an actor during the process execution. Additionally, since the modeling procedure is done to create a process template, the temporal situation of a process instance is usually just reflected by a state presentation and has no structural impact on the graph. An example of structural changes according to the process-state was introduced in Proviado [3]. With the VisModel an adaptable BPV framework was introduced and developed which offers a flexible and adaptable view on a process instance. Another flexible visualization mechanism was introduced by Jablonski and Götz [9] with a perspective-oriented process modeling approach, dividing the presentation of a process into different abstract perspective views. With the state propagation patterns [18] the challenge of different abstraction levels between the model layer EPC, BPMN, and the execution layer BPEL was addressed with the goal to transfer a process-state correctly into an abstract process presentation. ProView [10] is dealing with the special challenges of process aware information systems (PAIS) based process visualization and the need to pass changes to underlying process engines. Even if the mentioned research has introduced interesting tools and methods to go beyond the static process graph created by the process designer, all have in common that they are based on the control-flow oriented approaches like BPMN. A data perspective is available only as an add-on to the dominating activity-centric principles.

2.3 Visualization Factors

One purpose of a visualization is that the view should support the viewer in the best possible way to fulfill his/her tasks. Sophisticated business process visualization approaches [9, 10] achieve this by orienting the presentation to factors like the user perspective, the process-state, as well as the personal focus.

The users in a business process are playing a certain role like: a process designer, a manager, a process controller, or a process actor. Depending on their role, users have different *user perspectives* on a process to fulfill their individual tasks, which makes it to an important factor for any process adaptation.

Another factor for visualizing a process instance is the *process-state* being the result of the state of each process element. The importance of each element for a process visualization is mainly affected by its current influence to the process execution.

Both factors are inherent to the situation (*user perspectives* and *process-state*) and cannot be controlled by the user directly. If a visual presentation shows a process in a modified way, the user might want to have influence on this presentation by adding his *personal focus* to the view. This can be expressed by an interaction with the BPV and adds a third visualization factor.

These three factors claim an influence on a process visualization with different reasons and describe the points of interest for an adapted BPV.

Both, the mentioned research about business process modeling and execution and also the visualization approaches build the foundation for our work and lead us to the new concepts presented in the section 3 and 4.

3 A Unified Approach

In the following we will introduce a unified approach which offers a high flexibility during a process execution and serves the demands for knowledge intensive business processes [7]. By the integration of an ontology we take a knowledge-based system as a basis for this new approach. The artificial intelligence technique is supposed to offer some significant process contribution.

3.1 Motivation

As described in section 2.1, the data-centric and the constraint-based approaches follow the same declarative paradigm. In this work, we argue that both principles can be combined to a unified approach. We expect that this will offer a seamless scalability regarding flexibility and strictness, from an unstructured process task-list up to a narrow restrictive process model. The approach would also serve the demands of knowledge intensive processes by integrating data as a first-class citizen into the process [2]. Finally, we see the possibilities to assure the existing enterprise compliance rules by explicit restrictions based on additional activity constraints. With our work in the SEMAFLEX[3] [8] project, we have already considered this by combining flexible workflow management and knowledge-based document management. Through the combination of both approaches a semantic integration based on an ontology could be achieved. With the help of document classification and information extraction methods, the process relevant data within documents is transferred to the common knowledge base. By utilizing the knowledge base, the document data allows the identification of the associated process instance and corresponding process activities.

[3] SEMAFLEX is funded by Stiftung Rheinland-Pfalz für Innovation, grant no. 1158

Thereby, the documents can be used to recognize deviations from the current process-state and adaptions can be made to resynchronize the process.

With the unified approach, we do not only allow data to influence a process instance but to directly control its execution. Like in similar approaches [12] the demand for information within a process specifies the set of activities which can yield this information. As a result, all such activities whose preconditions are satisfied may be candidates for execution. From the data-centric perspective the preconditions are the availability of the required input information. However, through the combination with the constraint-based principle an additional layer for preconditions becomes possible. Such constraints may define direct dependencies between activities and may even guarantee a predefined execution order which can be used to fulfill compliance requirements.

Nonetheless, data has an essential influence on the process execution and can be delivered by manual activities, system activities, external sources like documents [8] and can be inferred based on the ontology. This mechanism will be explained in detail by the following example.

3.2 Example

Figure 2 shows a segment of an order process which delivers the information, whether a customer should be served on account or whether an upfront payment is required. The most important part in this example is the required information (Upfront payment), which is represented by a tristate value (true, false, unknown). All data elements are shown as a circle while the activities are presented in rectangles. Activities can be distinguished between manual activities like decide credit ranking manually and service activities. Edges between data and activities define the direction of the data flow. The edges between activities represent additional constraints. The transfer of an activity result can be obligated (solid lines) or optional (dashed lines).

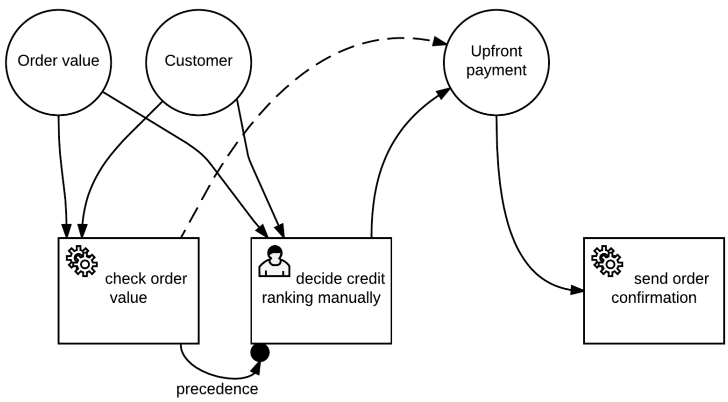

Fig. 2. Segment of an order process

The process is mainly data-driven as the activities depend on the input and the output data. This means that the activities are executable if the potential output data (Upfront payment) is still required and as soon as the necessary input data (Order value, Customer) is available. Since two activities can provide the required output, an additional precedence constraint [15] is defined. This constraint is used to assure that the decision regarding the payment condition is made in a controlled and predefined order, following the enterprise compliance rules. In the following, three different cases for this process segment are discussed and present the basic mechanisms of the introduced unified approach.

Case 1: Enterprise Knowledge. In the first case, we assume that the required information *Upfront payment* is available right from the beginning. The information might be delivered from outside by a document. However, besides such an explicit information source there is also another option to gain that information. The customer might be known through previous order-processes and his payments were always according the payment conditions. Thus, the customer is credit-worthy, which is stored in a global knowledge store. Now, the information *Upfront payment* could be deduced by the integrated knowledge base, utilizing the underlying ontology which combines the process data with a global knowledge store. This way and without an explicit activity, the results, produced by the inference mechanisms, have an impact on the further execution of the process. No matter if the answer for an *Upfront payment* is yes or no, since the required data is already available, none of the two activities which have this information as an output needs to be executed

Case 2: Check order value. In the case that the customer is new and thus no information about his credit-worthiness exists in the global knowledge store, the two activities are potentially executable from the data-perspective. Because of the additional constraint, only the activity *check order value* can be executed. As a system-activity, this can be performed without further user interaction. We assume that an upfront payment is required for any unknown customer if the *Order value* is above a certain threshold. In this case, the information *Upfront payment* is true and all other activities become obsolete again. If the *Order value* is below the level, the activity is successfully executed without delivering an answer for *Upfront payment* and the next activity can take over.

Case 3: Manual decision. This case happens if there is a new customer without knowledge about his credit-worthiness in the global knowledge store, who places an order above a certain *order value*. Now, all preconditions including the precedence constraint are fulfilled for a manual credit decision. A process actor, who is allowed to perform this activity, is asked for a decision, which can be *true* or *false*. However, since this is the last possibility to get an answer, this activity is obligated to deliver a result (represented by the solid line) in case of its execution.

The example has presented the data-oriented enactment of activities of the unified approach. In the execution, it follows the information-state rather than a predefined control-flow and offers a high degree of flexibility. To supervise the flexibility, constraints are used to guard predefined compliance rules.

The briefly presented unified approach combines the two declarative paradigms with a knowledge-based system. Besides the possibilities for an artificial process contribution, the ontology will be utilized for the following BPV approach.

4 A Semantically-Oriented Business Process Visualization

As presented in section 2.2, so far the research for adapting business process views focuses on control-flow oriented approaches like BPMN. Some studies have introduced adaptation techniques [3] like reduction and aggregation steps for the visualization of process instances considering process-state and user demands. However, these adaptation techniques cannot be easily transferred to the described unified approach because of its declarative and data-oriented principle.

4.1 Motivation

In general, the proposed unified approach requires a process visualization which allows to explore and identify the expected possibilities and allows the different groups of users to understand the process in its definition and its behavior during the execution. Primarily we see this demand for three user-groups, each with its own purpose:

- The process designer requires a view supportive for the process definition.
- The process controller requires a view which allows efficiently to identify delay in the process execution or potential risks.
- The process actor requires a view that serves best by the execution of single activities.

Beside the fact, that in the presented approach the relation between data and activities has a dominating role and a new visualization approach is required, the integrated knowledge base offers also new opportunities for a process view. The point of interest can be ascertained for each of the named groups and an adapted process visualization can be generated for each purpose. By utilizing the ontology, we pursue to create a view which presents the semantic relations between data and activities rather than just taking advantage of an activity arrangement by an imperative approach.

Considering the possibilities for deduced information mentioned above, humans have the need for a comprehensible presentation of the artificial process contribution. Since such new information is deduced based on the ontology, the source can be determined and the explanation can be presented by the visualization.

4.2 Visualization concept

The three introduced visualization factors (section 2.3) *user perspective*, *process-state*, and *personal focus* build the foundation of our visualization concept and define the individual points of interest together. These points of interest (explained in detail in the next section 4.3) and the knowledge base will be utilized to generate an adapted process view. Once the visualization is shown, three possible changes can take effect and will result in an updated process view. The user can change the process data directly or by performing an activity. The user can express his interest for a process element, which will change the personal focus. Finally, an external event (other user, system activities) can occur and the process data is changed as well.

To a large extent, this concept is similar to existing approaches. Even the user perspective and the view generation[3] are presented before in one way or another. The new aspect in this concept is the underlying data-centric paradigm as well as the knowledge base, which will be used for the view adaptation.

4.3 Points of Interest

A point of interest (POI) represents a process element which has some particular importance for the process visualization. Since the unified approach follows the data-oriented principles, a process element can either be an activity or a data-element. Any element which was recently changed or which is waiting for a change like executable activities has some elevated importance. With view to the user perspective, any activity which is assigned to the current user has also an elevated importance. If both factors (*user perspective* and *process-state*) coincide on the same point of interest, this can increase the importance even further. Additionally, through the *personal focus* the user can express his impression of importance. Thus, we get a list of points of interest (POIs) which filter the most important data and activity elements for the following process presentation.

The relevance of each further element depends on the individual meaning related to each POI. This meaning is reflected by the integrated knowledge base and the ontology can be utilized to calculate the relevance for each element. In a nutshell, the closer an element is related to a POI and the more meaningful the element is for the execution or understanding of the POI, the higher is its relevance. Such a relevance value can be used for each activity and data element for the following process adaptation.

4.4 View Adaptation

The view adaptation is the central transformation step of the view generator. With different techniques like reduction and aggregation, single elements up to process segments can be transformed and thus can be presented with a variable granularity. The most relevant elements can be presented in the highest level of detail while the less important elements can be presented in a more abstract view with a lower granularity. In the following, different adaptation methods are introduced, which are partially already examined [3] under the control-flow paradigm. These methods will be transferred to the introduced unified approach and take further advantage of the integrated knowledge base.

Reduction: One possibility to lower the granularity of a segment is the reduction step where single elements are taken out of the view. In existing BPV approaches often system activities where reduced with the expectation that they are less important than user activities. With the introduced approach, the knowledge base is used to calculate the individual relevance in semantic relation to the POIs.

Assuming that a specific data-element (D1) has just enough relevance for an unchanged presentation, the producing activity of this information might be not important enough and thus maybe reduced from the presentation. Unless the user is not clicking on D1 and thus increasing the relevance of this element by adding his personal focus, the producing activity remains invisible in the process visualization. Alternatively, only the producing activity of the specific information is presented and all alternative potential sources, like activities, which were not executed, are reduced.

Aggregation: Another option to reduce the granularity is to aggregate a group of activities or data elements to a single representative element. Unlike a reduction step where the elements are completely removed, the representing symbol is still visible and accessible and the user can expand it to the fine granularity any time. In existing BPV approaches, the aggregation step is used to combine activities which follow a narrow route within the control-flow and do not split to further activities. Under this new approach, elements can be grouped and aggregated by a similar meaning. For example, data-elements with the same type of relation to a common activity can be replaced by a single element, which substitutes the individual data-elements in the visualization.

Assuming that several data-elements (D1, D2, D3) were required for an already executed activity (A1), these data-elements share the same type of relation to the activity (A1). By replacing the data-elements with a single element (D1-3) the granularity of this process segment can be reduced.

Expansion: The most obvious way to adapt a view is lowering the granularity of process segments. However, with view to the underlying ontology and as described in section 3.1 with the unified approach, new information can also be deduced by inference steps. Referring to the example in section 3.2, the creditworthy might be stored in a global knowledge store. This source of information is not represented in the process as an explicit activity, nonetheless it has some impact to the process execution. With the method of expansion, the process view can be expanded by further elements which are defined in the ontology and which are not an explicit part of the process definition.

Assuming that a data-element (D1) is deduced from existing data (D2) by utilizing the relations defined by the ontology, the process view can expand D1 with a further data-element D2 by representing the common relation through an additional edge.

The basic idea of the view adaptation is to gain attention for the important elements of a process according to the POIs. With reduction and aggregation, we presented two methods to lower the granularity of process segments to achieve a simplified visualization by keeping the details of the important elements. With expansion, we presented a method to add further details to the important elements to get transparency for an artificial process contribution. For these three adaptation methods as well as for the calculation of the relevance of each process element we have utilized the integrated knowledge base.

5 Conclusion

In this paper, we have shown that the data-centric as well as the constraint-based approaches follow the same declarative paradigm and can be combined to a unified approach. For this, we expect a scalable flexibility, see the demands of knowledge intensive processes fulfilled, and can use constraints to define explicit restrictions to satisfy compliance rules. Through the integration of a knowledge based system, artificial intelligence methods should be able to participate directly in a process execution. This allows a division of labor between humans and an AI system. For a common understanding and a comprehensive presentation of the unified approach a new concept for business process visualization was presented.

Referring to existing research we have considered three visualization factors (process-state, user-perspective, personal focus) to determine the points of interest in a process instance. These POIs are used as a guideline and by utilizing the integrated knowledge base, the specific relevance for each process element can be calculated. With the help of three methods (reduction, aggregation, expansion) the granularity of process segments can be adjusted according to the calculated relevance. The adaptation of the process view is taking advantage of the integrated knowledge base and a semantically-oriented process visualization is conceivable.

In our ongoing work, we will implement the described unified approach in a prototype and will define the data-driven process based on an ontology. The described architecture will be realized to transfer a process instance to a visual representation. The methods for a process adaption will be realized to prove the concept of a semantically-oriented process visualization.

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