Advanced Context Processing for Business Process Execution Adjustment

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Abstract. Business process execution is affected by various contextual factors. Context-aware business processes consider the contextual factors during process design and execution. There is a large variety of possible context situations and their impact on the business process is difficult to know in advance. To this end an advanced context processing to adjust business process execution is proposed. It allows flexible definition of meaningful context categories using measurable properties of the context and run-time adjustment of the categories. The adjustment is performed depending on the progress towards achieving business goals. The proposal is demonstrated by a travel management example.

Keywords: Business process · Context · Adjustment · Performance indicators

1 Introduction

Adaptation of business process (BP) execution to changes in the real world emerges as a challenge. Context is any information that can be used to characterize the situation of an entity [1]. An information system (IS) is context-aware if it uses context to provide relevant information and/or services to the user. Business services and processes are among areas significantly affected by context [2]. To address the need to adjust businesses and IS, the Capability Driven Development (CDD) approach [3, 4] has been proposed. CDD supports business service provisioning by ensuring that business capabilities are delivered in accordance to goals in various contexts. CDD relies on Enterprise Modeling, context processing, as well as knowledge and variability management to design capabilities. The capability delivery is dynamically adjusted to improve delivery performance depending on the context.

The major issues of *designing and running* context aware BP are: (1) diversity of process execution circumstances causes excessive variability in BP designs; (2) not all context situations can be foreseen at design time; and (3) relationships among context and BP performance are not well-understood. Issues (1) and (2) are addressed by categorizing context values into a set of meaningful values, for which process design and execution is differentiated. Issue (3) is addressed by adjusting context definitions at run-time using a search procedure.

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The objective of this paper is *to elaborate a method for advanced context processing based on using context definition run-time adjustments to improve performance of BP execution.*

A running example of a travel management process of a university is used. BPMN [5] is used for BP modeling and to indicate context dependencies. The context is modeled with the approach proposed in [6]. It is refined by elaborating a method for advanced context processing that includes context representation and specification of context processing expressions during design of the context aware IS and context processing adjustment during run-time of the context aware IS. The context processing adjustment is performed to optimize process execution performance as prescribed by BP goals. The context processing is evaluated using a simulation study. The contributions of the paper are (1) a flexible approach for defining meaningful context categories and (2) a search method for redefining the categories if sufficient information was unavailable at design time.

The rest of the paper is organized as follows. Section 2 summarizes related work on BP contextualization. The research framework and the running example are introduced in Sect. 3. Section 4 presents BP contextualization and Sect. 5 presents the advanced context processing is presented. Section 6 reports evaluation results and Sect. 7 presents concluding remarks.

2 Related Work

BP variants is currently one of the most frequently used approaches for supporting adjustment of BP for specific conditions and requirements. Process variants can be constructed either by configuration or adaptation [7]. In the case of adaptation, the variants are designed by applying BP change operations such as insertion, deletion of tasks or other process flow elements. In the execution phase, Switching between the process variants is possible also during the process execution phase to deal with dynamic context changes [8]. Principles of autonomic computing are used for process management to maintain the process execution performance within certain bounds [9] by selecting appropriate operational variants depending on the current execution performance and context. Reference [10] proposes a dynamic adaption of service composition and can be seen as opposite to static adaptation that requires shutting down the IS for manual modification. The key issues of dynamic adaptation are context awareness, adaptation policies, supporting infrastructure and verification.

The adaptive and context aware workflows [11, 12] are used to provide process-oriented services tailored to the current operating circumstances using either context data to alter workflow execution sequence without changing the underlying schema or running workflow instance or adapt the workflow schema or running instances. Majority of the surveyed solutions deal with workflow instance adaption [12].

Various techniques ranging from judgmental to data mining [13] can be used to identify relevant context factors. Contextual analysis is applied to develop process execution variants depending on the process execution context in [14]. A method for dynamic configuration of BP according to the context at run-time is elaborated in [15].

These works primarily address the identification of the context factors; context processing and interpretation is rarely considered.

BP exception handling patterns provide possible solutions for dealing with various exceptional circumstances during the process execution [16]. A method for using context-based configuration rules for post-design adaptation of case management processes has been elaborated in [17]. It demonstrates that context information is important for driving BP adaption.

3 Research Framework

This research is part of an EC FP7 project CaaS – Capability as a Service for Digital Enterprises (no. 611351). Its objective is to develop an approach and an environment for context dependent design and delivery of business services, including adjustments at run-time. CaaS has of three industrial cases at Everis (Spain), FreshT (UK), and SIV (Germany). The validation at each company started with requirements analysis [18] followed by capability design [19, 20]. The next step is development of the connections between the capability designs and the supporting IS, executing the capabilities as well as adjusting them at run-time. The travel case presents the initial elaboration and validation by the means of simulation of the CDD method components for context processing based on using context definition run-time adjustments. The overall ethos of the research approach taken is that of Design Science [21]. The travel case is used in the project as initial design-evaluation cycle that is followed by separate design-evaluation cycles at each use case company.

3.1 Running Example

The travel management process consists of four main activities (Fig. 1). The travel planning specifies purpose, destination and time of the business trip. The travel budgeting specifies the planned travel expenses in compliance with internal and external regulatory requirements. During the trip, the travel objectives are achieved and expenses are accumulated. The travel results and expenses are reported upon returning.

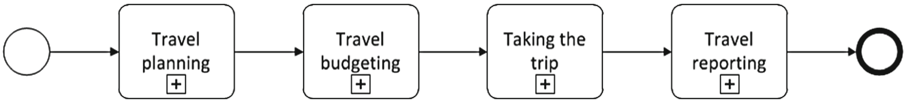


Fig. 1. Overall travel management process

Table 1 lists some of the business goals for this process and performance indicators that are deemed important for the case. In the CaaS use cases the goals and indicators are represented by a goal model. The business trip needs to contribute university's academic outcomes (goal G1) and the travel costs need to be optimized (G2). Trips are affected by uncertainties such as weather conditions and unexpected events causing delays, leading to extra costs and scheduling conflicts, in spite of which trips need to be completed on time (G3). Trips take time away from other academic activities; hence scheduling conflicts should be minimal (G4). The paperwork for reporting the trip should be minimized (G5).

Table 1. The travel management goals and associated performance indicators

Goal	Performance indicator
G1. To maximize traveling outcomes	I_1. Number of resulting publications I_2. Number of contacts established
G2. To optimize travel costs	I_3. Average travel costs per trip
G3. To complete trip on time	I_4. Number of trips not completed on time I_5. Sum of days late
G4. To minimize scheduling conflicts	I_6. Average severity of scheduling conflicts
G5. To minimize travel management paperwork	I_7. Percentage of trips requiring additional evaluation/approvals

Goals achievement depends on the environmental factors and circumstances. E.g. travel costs might increase due to a major event at the planned destination, or a trip is delayed due to weather or unexpected important events are added to the organizational calendar. The process execution context can capture some of these circumstances. Therefore, contextualization of the travel management process is highly desirable.

4 Context Aware Business Process

BP contextualization is performed in three steps: (1) association of BP activities with business goals and appropriate performance measures; (2) identification of process elements affected by the context; (3) reasoning about relationships among the business goals and the context.

BP have specific goals to be achieved. The goals will be used to adjust context processing. The process execution is measured for individual process instances using selected process indicators. The indicators are defined following guidelines provided in [22]. The indicators can be graphically represented in the process model as data objects. The context dependence can be represented as: (a) context dependent script tasks; (b) decision-making at the complex gateway; (c) throwing a regular event; and (d) throwing an attached event (Fig. 2). The elements are chosen because they allow evaluation of context depend expressions although other process flow elements could also take context as input data. The context is represented as data objects attached to relevant flow elements. Relations between context and the process elements are indicated without further elaboration of context processing.

To represent context dependent branching decisions using complex gateways we assume that context values can be categorized in a meaningful categories and every outgoing branch of the context dependent complex gateway corresponds to treatment

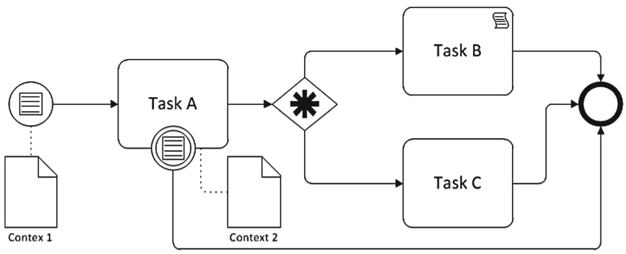


Fig. 2. BPMN elements used for representing context dependence

of one of these categories. The task is to establish these categories and if necessary to adjust the categories to better comply with the BP goals.

Advanced context processing takes place at both design time and run-time. The BP is designed and its context dependent features are specified at the design time. If the BP is developed using executable BPMN, it can be readily deployed and executed in the run-time environment. Execution of BP instances also includes capturing the context data and feeding them to the running BP and monitoring the process performance. The context processing is adjusted during the run-time using the context data and the process performance measures. The adjustment is done without redeploying the BP.

The travel planning activity is contextualized (Fig. 3). The goals relevant to this activity are G1, G3, G4 and G5. The tasks are affected by context factors - *travel conditions*, *calendar* and *weather*. The travel conditions are general conditions at the planned destination, e.g., the US Department of State issuing warnings and alerts for visiting certain countries. The calendar is a university-wide calendar of events to evaluate significance of overlapping between planned travel dates and other events. The calendar contains both general events of varying importance and events assigned to specific employees. The weather context affects ability to complete trips on time.

The process has variability to deal with the context. If travel conditions are hazardous the trip is canceled. Procedures for addressing calendar and weather concerns are also proposed. Depending of perceived severity of the calendar conflicts, their resolution is performed or warning suggesting optional conflict resolution is generated.

5 Context Processing

Context processing is done in three stages: (1) context representation; (2) design-time processing including specifying expressions for context categorization; and (3) run-time processing, i.e. adjusting the context categorization according to situation.

5.1 Context Representation

The context factors affecting the process execution are referred as to context elements [6]. The context categories are defined using the context element range (Fig. 4).

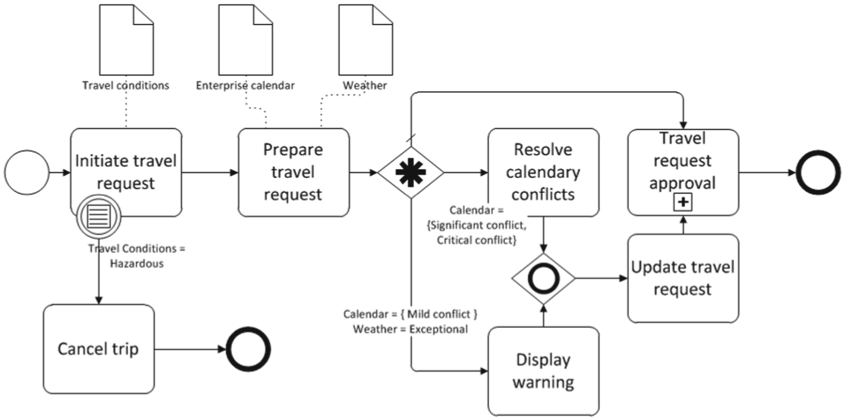


Fig. 3. The expanded travel planning activity

Contextual circumstances are captured using measurable properties (MP) that measure the actual phenomena affecting the process. Context elements are an interpretation of the measurements in the business sense. The context element range is identified during the process design. If a context element is associated with a complex gateway then the process model should have a branch for processing every category in the range.

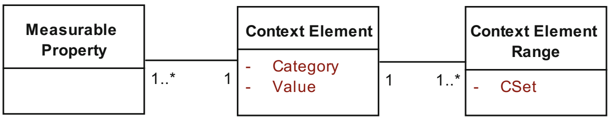


Fig. 4. Concepts used for context representation

MP give flexibility for changing context processing without changing the BP. E.g., if additional of MP become available they can be used to evaluate the context element category more precisely.

Figure 3 shows the contextualized travel planning activity Travel conditions, Calendar and Weather are the context elements. The Travel conditions context element has Context Element Range (Normal, Hazardous). The context element is measured using the US Department of State warnings and alerts for visiting certain countries. It there is a warning or an alert issued for the planned destination then the travel conditions are Hazardous (in this case category and value are the same since the measure is already categorical) otherwise Travel conditions are Normal. These kinds of warnings can be seen as rather coarse data and other MP from different context data providers can be added later to evaluate travel conditions more precisely.

5.2 Design-Time Processing

Transformation of MP into context element values is defined during process design. Given the ith context element and MP $P_i = (p_{i1}, \ldots, p_{iM})$, the context element value V_i is calculated as

$$V_i = f(P_i) \tag{1}$$

Every context element has its range of context elements defined as $R_i = (r_{i1}, \ldots, r_{iN})$.

The relationship between the context element value and range is expressed as

$$C_i = \begin{cases} r_{ij}, b_{ij}^L \leq V_i < b_{ij}^U \\ r_{iN}, V_i \geq b_{iN-1}^U \end{cases} \tag{2}$$

where $b_{ij}^L = \phi((j-1)\Delta V_i)$ is the lower bound for jth range and $b_{ij}^U = \phi(j \times \Delta V_i)$ is the upper bound for the jth range. $\Delta V_i = N_i^{-1}(\max(V_i) - \min(V_i))$ and ϕ is a function to be specified.

The categorization of the context depends upon decisions made by business analysis and process owners. Some of the categories occur naturally in the business environment while others are derived as a result of expert judgment. In the case of limited information, the categories ought to be reevaluated as more data become available. The way categories are defined can be used as an instrument to manage achievement of the process goals. E.g., in the travel management case there are two conflicting goals: (1) minimizing the calendar conflicts among the travel dates and other events; and (2) minimizing travel management paperwork.

5.3 Run-Time Adjustment

Relationships between context categories and goals are implemented as run-time adjustments. The process of run-time adjustment is as follows:

- instances of context aware BP are executed
- performance measurements are accumulated and goals are evaluated
- if performance targets are not met, perform adjustment of the context categorization expression (Eq. 3)
- apply the new categorization expression to newly created process instances.

The adjustment can be made automatically using formalized adjustment rules although a human approval might often be needed. The adjustments are implemented at run-time without redeploying the BP execution solution. They are implemented by redefining Eqs. 2 and 3. The expressions depend on functional form of f and its parameters referred as to ω. The values of ω are changed according to observed values of indicators. An exact relationship between context categories and indicators is unknown, hence a search approach is used to identify proper categories.

$$\omega_i = \begin{cases} \omega_i + \Delta\omega_i, I_j < I_j^{Target} \\ \omega_i - \Delta\omega_i, I_j \gg I_j^{Target} \end{cases} \quad (3)$$

The dependency implies that greater values of ω contribute to improving indicator I_j (depending on indicator, the opposite may be true and the sign is reversed). The much more relation $\gg$ is used to indicate that reduction should be made only in regards to other conflicting indicators, for which impact of ω is different.

In the travel management case, larger ω is preferred to reduce calendar conflicts because more cases are classified as having significant or severe conflict and the resolution activity should take place. However, that might also cause an increasing amount of paperwork and indicator I_7 prefers smaller values of ω.

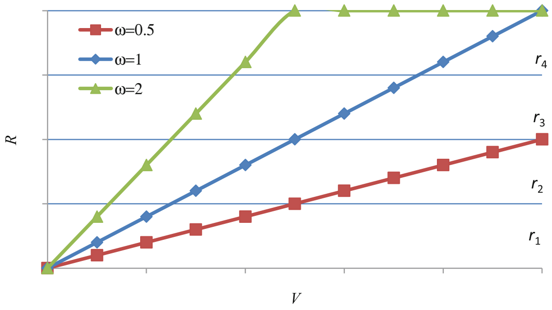


Fig. 5. Impact of ω on categorization results

If ϕ is a linear function, the impact of ω on categorization is illustrated in Fig. 5, where context element category is shown depending on the context element value. $\omega = 1$ gives evenly distributed ranges of context values. If ω is increased more context values are categorized to belonging to the upper category. If ω is decreased majority of context values fall into the lower categories.

If the BP execution environment is relatively steady then a categorization steady-state can be achieved. In that case, the adjustment is used to deal with the initial lack of information during the process design. However, if the environment is not stable, then the adjustment allows for continuous updating of the categories.

6 Evaluation

The proposed advanced context processing is evaluated using the travel management case. The evaluation objective is to demonstrate the impact of run-time adjustment of context processing on BP performance. The evaluation is performed by simulating multiple travel requests and contextual data and using these to adjust context processing. The simulation focuses only on the travel planning activity and, more specifically, on relations between the calendar context element and goals G4 and G5.

The calendar context element is defined in Table 2. The calendar context element relies on the university-wide calendar of events to evaluate the significance of overlapping between planned travel dates and other events. The calendar contains both general events of varying importance and events assigned to specific employees.

Table 2. Definition of the Calendar context element

Context element	Measurable properties	Context Element Range
Calendar	p_1 is the count of the scheduled hours of regular importance overlapping with travel dates	No conflict, Mild conflict,
	p_2 is the count of the scheduled hours assigned to the employee and overlapping with the travel dates p_3 is the count of the scheduled hours overlapping with the travel dates and marked as high importance	Significant conflict, Critical Conflict

The context element value is calculated as

$$V_c = \frac{w_1 p_1 + w_2 p_2 + w_3 p_3}{w_3 H}, \tag{4}$$

where c refers to the calendar context element, H is the total duration of the trip in hours, p_1 is the count of the scheduled hours of regular importance overlapping with travel dates, p_2 is the count of the scheduled hours assigned to the employee and overlapping with the travel dates, p_3 is the count of the scheduled hours overlapping with the travel dates and marked as high importance, and w_j are appropriate weight coefficients indicating importance of every measurable property in calculating the measure.

The context element category is evaluated following Eq. 2 and using a linear adjustment function, i.e., the lower and upper bounds are reformulated as $b_{cj}^{L} = \omega(j-1)\Delta V_c$ and $b_{ij}^{U} = \omega \times j \times \Delta V_c$, respectively.

Performance indicators I_6 and I_7 reference to goals G4 and G5, measure the travel planning activity and the target values are set as 0.1 and 20 %, respectively. I_6 is evaluated using expression Eq. 4 and I_7 is measured as a percentage of trips categorized as having significant of critical conflict and thus requiring additional conflict resolution (rescheduling, finding replacement etc.). It is reasoned that:

1. More trips categorized as having a high level of conflict results into increasing amount of paperwork, thus, negatively affecting goal G5;
2. More trips categorized as having a low level of conflict results into increasing level of scheduling conflicts, thus, negatively affecting goal G4.

The goals are mutually contradicting. Achieving G5 would favor adjustment by decreasing ω while achieving G4 would favor adjustment by increasing ω.

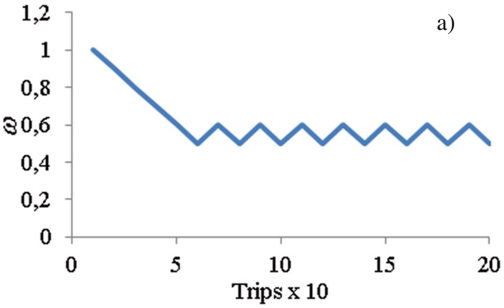
The process is simulated as follows: (1) generate trip data including starting date, duration and destination; (2) generate the measurable properties; (3) evaluate context category; (4) simulate scheduling conflict resolution; (5) evaluate process performance; and (6) update ω using Eq. 3.

The trip duration is distributed as N(4,1), where N denotes normal distribution with mean 4 and standard deviation 1. Similarly, MP p_1, p_2 and p_3 are generated using N(1,1), N(2,1) and N(0.8, 0.5), respectively. The conflict resolution is simulated using the following rules. If R_c = "No conflict" no adjustment is performed. If R_c = "Mild conflict" then a non-binding warning is displayed to an employee about presence of the scheduling conflict and the employee voluntary resolves some of the scheduling conflicts. The reduction is done by h percent where $h_1 \sim$ N(10,5) (it is applied to all MP). If $R_c \in$ (Significant conflict, Critical conflict) an employee enters the conflict resolution task resulting in conflict reduction by h percent, where h is distributed N (30,10) and N(75,25) for respective categories. These values imply that all conflicts are not necessarily resolved, though the percentage of conflicts resolved correlates with the severity of scheduling conflicts as identified by the calendar context element.

The context processing adjustment is performed according to both I_6 and I_7. ω is increased if the I_6 target is not met and is decreased if I_7 target is not met. The starting value of ω is one. 500 trips are simulated and ω is updated after every 10 trips with $\Delta\omega = 0.1$.

Figure 6a shows the convergence of ω values according to a number of adjustments, suggesting that the search procedure quickly identifies an improved categorization of the Calendar context element. Settling on $\omega < 1$ indicates that the process goals can be better achieved if fewer cases have high level of conflict. ω fluctuates between 0.5 and 0.6 because G4 and G5 are contradicting each other and an equilibrium satisfying both goals cannot be found (Fig. 6b). At $\omega = 0.5$, the paperwork reduction is achieved but the severity of scheduling conflicts target is not satisfied. Increasing of ω leads to deterioration of I_7. The figure also shows evaluation results for two other selected values of ω. The results highlight that for this case the adjustment alone cannot ensure achieving all business goals and other process improvement options are needed.

Obviously, the evaluation results depend upon the way I_6 is calculated and other parameters. These parameters are set up during the context aware process design and can be updated during the process execution if necessary.



b)

ω	I_6	I_7
1 (initial)	0.07	93
0.5 (adjusted)	0.14	1
0.6 (adjusted)	0.13	15
2	0.04	99
0.2	0.15	0

Fig. 6. Evaluation results: (a) convergence of ω; and (b) BP performance

7 Concluding Remarks and Future Work

The paper investigated the advanced context processing as a part of research on the CDD of context aware IS. The advanced context processing allows defining the context in a way of minimizing BP variability and maximizing achievement of the business goals. The process variations are developed only for the context categories meaningful to the business and run-time adjustments allow realigning these categories to improve BP execution performance.

More complex functional relationships between the context value and the context category can be defined. E.g., a rule can be added that if $p_1 > 0$ then R_c ="Critical conflict". This requires additional design and convergence of the search procedure would be slower (i.e., it would be harder to identify appropriate categories). The search procedure could be improved in various ways. E.g., variable $\Delta\omega$ could be used to find an optimal value of ω though that would be possible only in the stable environment.

The run-time adjustment of context categories is not applicable for all types of business decisions. In many situations any changes in categories would require additional validation and approval. If that is a case, then the run-time adjustment provides suggestions for changing the way context is processed in the BP, and proposed changes are not implemented automatically.

The next step of this research is validation of the advanced context processing using the CaaS use cases. This research will also serve as input for developing an application visualizing changes in the context and adjustments performed.

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