Context-Awareness for Adequate Business Process Modelling

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Abstract: **This paper investigates context awareness in business process modelling (BPM). It introduces a context model for BPM (CM4BPM) and a role-based business process model (RBPM), and presents an approach allowing enacting processes with respect to the context. Decisions driving business processes enactment are based on context related knowledge. The proposed approach consists on using contextual knowledge in order to enhance the adequacy of the assignments during the enactment of the business processes, it can be used to improve the design and implementation of business processes using existing process modeling languages in order to allow the support of context-aware process enactment.**

Keywords:Business Process Modelling, Process Flexibility, Context-aware Computing.

I. Introduction

A business process (BP) is defined as a set of logically related tasks performed to achieve a defined business outcome [5]. [27] extends the above definition by introducing the concept of *role*, stating that a business process is a set of one or more linked procedures or activities that collectively realise a business objective or policy goal, normally within the context of an organisational structure which defines functional roles and relationships. Modelling business processes consists in capturing processes and highlighting significant aspects of the business. During the two late decades, several sorts of techniques and tools dealing with business process modelling were proposed [33]: traditional input-process-output techniques, conversation-based techniques, techniques based on role modelling, system thinking and system dynamics techniques, and constraint based representations techniques. Among these techniques, those based on the role modelling, for instance [4], have the advantage of supporting the well-known separation of duties principle (*SoD*). "*The purpose of the SoD is a policy to ensure that failures of omission or commission within an organisation are caused only by collusion among individuals and, therefore, are riskier and less likely, and that chances of collusion are minimized by assigning individuals of different skills or divergent interests to separate tasks*" [8], [11]. Furthermore, the concept of *role* not only allows underlining the responsibility of each actor and reflects the organisational structure but also improves the understanding of the way responsibilities are achieved. We argue that adopting role based methods for modelling business processes is useful, particularly if they are flexible enough to meet business process flexibility requirements, especially organisational, functional and operational requirements. Nevertheless business process modelling approaches, dealing with role descriptions are not satisfactory to meet flexibility requirements. These approaches, for instance, Role-Interaction-Networks [24] and Role-Activity-Diagrams [19], represent roles as sets of ordered activities or interactions: they introduce "swim-lanes" to indicate the responsibilities of participants; and to describe the interactions between pairs of roles, from a source to a target role. In addition, [1] improves the understandability of business process (BP) models by making explicit roles present in BPs. Its main contribution with respect to [19] and [24] is to represent explicitly physical objects that a role needs to execute its actions. A role is represented with a rectangle that includes a set of actions, sequential constraints between them, tools and materials that a specialist needs in his craft to perform the actions. Nevertheless, the approach proposed in [1] does not allow this sequence of actions to be executed by actors having different competencies, according to the situation in hand.

As discussed previously, the concept of *role* is an expressive means for modelling business processes (BP). Therefore, our reflection is based on this concept. As well, due to the economic and technological progress, customers' expectations are becoming more and more specific and varied following the context in which expectations are formulated.

Hence, context related knowledge (*CRK*) becomes an essential resource to adapt the behaviour of BPs. A conventional BP model may fit customers' expectations in a given context and not in another one. Although context-awareness has been investigated in several domains, there are numerous other areas of computer science that can take advantages from context-awareness, for instance business process modelling.

Despite innovative works proposed by the BP community, there is a lack of approaches that support adaptability according to the contextual requirements of business process instances. The ability to integrate the context related knowledge allows BP models to be active, flexible, and able to express a variety of business rules according to various situations. These features provide an enhanced adequacy to stakeholders' requirements. Flexibility and adequacy have been the focus of many researches [17], [20], [22], [23], [25], [26]. We define flexibility as "the capacity of making a compromise between, first, satisfying, rapidly and easily, the business requirements in terms of adaptability when organisational, functional and/or operational changes occur; and, second, keeping effectiveness".

Dynamic changes and unexpected events cause divergence between the predefined process model and the current instances. For the above mentioned reasons, it is interesting to make business process models context-aware so that their instances can be adapted to the current situations and be more coherent with the stakeholders' needs. Our belief is that BPM could greatly benefit from being context aware.

We introduce in this paper an approach for business process (BP) modelling which supports the explicit definition of the context related knowledge in order to make instance adaptations "context-aware". In other words, decisions made during process instantiations are based on context related knowledge. The approach consists of using contextual knowledge in order to enhance the adequacy and the coherence of the assignments during the enactment of the business processes, for instance, actor-to-role or process-to-role assignments. In order to use efficiently the contextual information in business process enactment rules, the context related knowledge (CRK) should be formally defined.

The reminder of this paper is structured as follows. Section 2 discusses background and related works. In section 3, we introduce our basic approach supporting the role-based BP modelling. In section 4, we introduce our approach for handling the context related knowledge and we define the underlining way-of-modelling and way-of-working that can be implemented using any suitable programming environment. Section 5 concludes the paper and sets perspectives for our future work.

II. BACKGROUND AND RELATED WORK

A. BP modelling

From our point of view, BP modelling consists in capturing the organisational knowledge according to various perspectives with respect to the modelling purpose and the situation. Five perspectives, namely *functional, process, organisation, information, operation,* have been proposed in [38] and extended in [39] with a sixth one: the *intentional perspective*. On the other hand, literature provides various process modeling formalisms that can be roughly classified into four categories: *activity oriented*, *product oriented*, *decision oriented and conversation oriented models* [18]. The most commonly used formalisms are *activity-oriented* [5], [9], [13], [10]. They are useful for representing functional and process perspectives of the BPs [18]. The resulting BP definitions (models) have the advantage to be easily transformable in executable code but the disadvantage of being prescriptive and rigid. The most recent modelling formalisms are *goal-oriented* [15], [21] and *decision-oriented* [16], [17], [18]. They are more adequate than those driven by activities for capturing the "*Why" perspective which is essential to handle flexibility requirements*".

B. Context-awareness

Historically, the concept of context has been adapted from linguistics, referring to the meaning that must be inferred from the adjacent text [30]. The context has various meanings according to the application. Dey et al. [6] define context as "*any information that can be used to characterize the situation of entities that are considered relevant to the interaction between a user and an application, including the user and the application themselves*". Winograd [31] gives a more specific and role-based definition: "*context is an operational term: something is context because of the way it is used in interpretation, not due to its inherent properties*". Most recently, Coutaz et al. [29] define context as "*is not simply the state of a predefined environment with a fixed set of interaction resources. It is part of a process of interacting with an ever-changing environment composed of reconfigurable, migratory, distributed, and multiscale resource*". The context plays an important role in several scientific domains such as natural language semantics, artificial intelligence, knowledge management, and web systems engineering. In the domain of BP modelling, context awareness is a relatively new field of research. [28]. In [22], a BP context is defined as: "*The minimum of variables containing all relevant information that impact the design and execution of a BP*". A context-aware modelling framework has been introduced in [29].

With respect to the literature, context is often characterised by a space. For instance, [12] characterises the context in the domain of artificial intelligence by a space that includes a number of dimensions or parameters (e.g. *time*, *location*). Maus [14] introduces parameters for a workflow context space (e.g. *function*, *behaviour*, *causality*).

Regarding the context modelling, most of the existing context models are based on one of the following methods: Set theory [34], [35], Directed Graph [30], First-order Logic [36], Preferences and user Profiles [37].

III. ROLE-BASED BUSINESS PROCESS MODELLING

One of the major limitations of the current techniques, based on role and activity modelling, is that a BP is considered as a set of operations or activities with a predefined order. This feature increases rigidity by imposing an order to perform operations. More flexibility can be provided thanks to extension mechanisms based on the concept of role. As organisations are structured as networks of BPs in order to achieve their business goals, a BP can be first analysed in terms of *roles* played by actors and the corresponding functions. During the execution of a BP, actors perform functions that specify the responsibilities and the work included in swim-lanes in classical activity-oriented representation formalisms. A function is similar to the concept of task in OSSAD [7] i.e. the crosselling between a BP and a role. A business goal is reached by executing a BP which comprises many roles and consequently many functions. During the execution of a BP, actors perform operations. Roles and functions are usually more static than actors and operations are. The central concepts in our approach are the *role* and the *function*. From our point of view, a *role* is a semantic construct about which business rules and other concepts can be formulated in a more generic way [23]. It can represent competency to realise particular functions, e.g. "an engineer", or can embody authority and responsibility, e.g. "a project supervisor".

As shown in Figure 1, each actor belongs to at least one organisational unit and is assigned to appropriate roles based on his responsibilities and qualifications. The concept of *function* serves as a link between roles and operations: A function is defined as a collection of operational goals satisfied by achieving operations. A function includes several operational goals because it is not achieved performing straightforward and continuous operations without any interaction with other roles.

The set of operations allowing a role (played by an actor during the process occurrence) to achieve an operational goal is defined by the concept of activity in [27]. The difference in our proposition is the following. We propose:

- To define this piece of responsibility of a role in the intentional level (operational goal),
- Then to go deeply in the specification of this operational goal (dealt with as a black box in usual workflow formalisms),
- And finally to specify the operations which performance acts on the business objects and allows achieving the operational goal.

Regarding organisational, operational and functional perspectives, providing the concept of function as a joint offers a more flexible way to allow an actor to perform an operation than in the opposite one in which roles are directly linked to operations. As new policies are incorporated, actors can be easily reassigned from one role to another as usually, but also from one function (the responsibility of a role in a *specific* BP) to another which is not possible using other approaches; roles can be associated with new functions; and functions can be associated with new operational goals and operations. In addition, functions can be dissociated from roles; operations and operational goals can also be split-up from functions if needed.

In order to highlight our motivation behind the use of the concept of *function*, let us consider the following situations: Situation 1: a new organisation is set up and it proves to be necessary to distribute the responsibilities of each actor differently. Situation 2: a responsibly has to evolve. For dealing with Situation 1 and Situation 2, classical approaches require checking all operation-to-role assignments and modifying them when required. This task is time consuming and includes risk of errors. Moreover, competitive environments require quick reactions to changes and do not accept inaccuracies. In our approach, to deal with Situation 1, we have only to modify some function-to-role assignments, while actors keep their roles, with up-to-date responsibilities. Situation 2 requires simply to modify some operational goal-to-function and/or operation-to-operational goal assignments, while roles keep their functions, with up-to-date operations. Thus our approach supports adaptation to organisational, functional, behavioural and operational changes using more local modifications than the traditional approaches. In addition, conventional role based approaches define processes in such manner that a given operation *op1* should be executed by a specific role *r1*. However, in special cases, *op1* could not be performed by *r1*. Based on this observation, we identified an additional aspect of flexibility: in a particular process instance, a function may be performed by selecting one of the candidate roles provided rather than a fixed role. Accordingly, we consider that a BP should be relied to functions rather than operations. So, instead of defining the pre-order of the operations involved in the process, we have simply to precise which functions are required for the BP performance.

Each process can be considered as a mapping of many roles and many functions with a number of constraints. Each BP instance is considered as a mapping of many actors and many functions, respecting also some constraints. A function can be held by several roles in several contexts with regard to the current situation and the flexibility purposes.

As shown in Figure 1, the role driven business process modelling (RBPM) approach is composed of entities and relationships between them which are also called assignment relationships. In evolving environments, the stakeholders' expectations change unpredictably. Thus, it is inaccurate to identify the behavior of all occurrences of a BP in a static way. With respect to RBPM, it is difficult to define BPs, roles requested to participate in their achievement, actors playing roles, operational-goals satisfying functions and operations requested for achieving operational goals in a dynamic manner. Therefore, a context sensitive BP approach offers the ability to adapt the BP behavior to changing contexts.

IV. Context-aware BP Modelling

As mentioned above, it is often required to consider various context related knowledge in enactment decisions, especially in highly changing environments.

The modeling language required to specify business process models and its component concepts (e.g. *activity*, *role*) can be described by a meta-model. The meta-model corresponds to the level 3 of the OMG four-layer-architecture [32]. The business process model instantiates the meta-model in order to represent a domain specific BP definition. An instance represents an actual BP.

Our proposal highlights the value of the context-related knowledge in the guidance that may be provided to support decisions among assignment options while enacting a BP model. The approach proposed in this paper can be applied to any meta-model aiming to define BP models. Nevertheless, our reasoning in the following and our proposal are based on the RBPM meta-model [23]. Therefore, the actor-to-role assignments, for instance, are often sensitive to such context information. To deal with a dynamically changing context, a first option is to rapidly change assignment relationships according to the changes of the situation. A second option is to define situational assignments which take into consideration context related knowledge in the instantiation decisions.

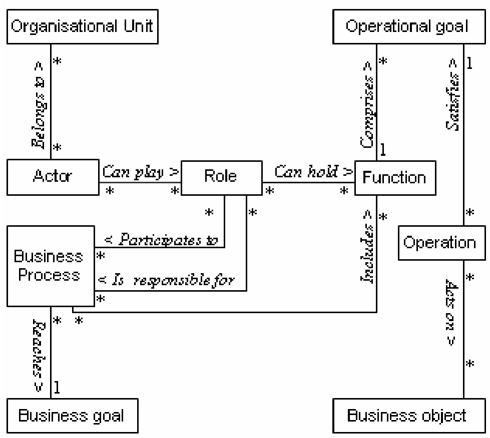

Figure 1. The meta-model of RBPM

The context related knowledge (CRK) may be supported in different parts of a process model.

With respect to RBPM, CRK (i) may concern BP elements, for instance, the "*competency*" concerns the entity "*actor*" of the BP meta-model, and (ii) has impact on assignment relations, for example, the "*experience*" and the "*urgency*", together, have impact on the actor-to-role assignment: in an urgent situation, it is better to assign a given role to an expert actor rather than a novice one.

The introduction of the context has impact on all assignment relationships of RBPM. However, we focus on only some of them which are relevant for the purpose of this paper. With respect to the assignment relation *can play*, actors are assigned to roles according to their capability in a particular context. Let us take an example: *Steve* belongs to the *loan handling service*, he plays the role "*Loan_assistant"* and he has a *good experience* in the domain of loan handling. He can be assigned to the role "*Loan_manager"* if and only if all actors which can play the role "*Loan_manager"* are *unavailable*. Note that this assignment is related to a specific context and can take place nowhere else:

<<"He has a *good experience*" and all the actors that play "*Loan_handling" are unavailable*>>

With respect to the assignment relationship *can hold*, conventional role-based approaches define processes in such manner that a given operation should be executed by one specific role. But, this can not be always possible at the instance level. In fact, if all actors playing a given role are unavailable, a function should be performed by selecting one of the roles provided rather the fixed role. Including the context allows answering this question: "In which context a function can be held by a given role?". Then, functions can be held by several roles in several contexts for flexibility and adequacy purposes. In the following, we set some questions aiming to capture the requirements related to the context knowledge support:

- Which functions a business process comprises in an "*urgent situation*"?
- Which roles a particular employee "*usually*" holds?
- Which operations an operational goal requires at which "*point of time*"?

To answer the above mentioned questions, the following issues need to be discussed.

- What kind of *CRK* is relevant to BP modelling?
- Can we categorise the contextual information and how?
- Which kind of contextual information is relevant for a specific BP?
- How the *CRK* can be used during the instantiation of business processes?
- Is there a relevance relationship between the nature of the context and the BP model components?

A. Context Related Knowledge Elicitation

We presume that the *CRK* is closed to the application domain taken into account. So one should first understand and find out about the organisation, second, identify the business processes that are currently performed, and third identify the internal and external dependencies between elements of the organisation (e.g. actors, BPs).

We argue that any information reflecting changing circumstances during the modelling and the execution of a BP can be considered as contextual information.

Definition 1: *Context related knowledge (CRK)*: "*the collection of implicit assumptions that is required to activate accurate assignments in the business process at the model and/or instance level*". Thus, the context related knowledge covers any circumstance that impacts the assignement relations.

We distinguish between *static* CRK e.g. "*date of birth*", "*social security number*", and *dynamic* CRK (e.g. "*availability*").

- *Static CRK* relates to knowledge that can be evaluated at design time of a process model. Decisions that are based on these CRK can thus be made at the build (design) time.

- *Dynamic CRK* relates to knowledge that can only be evaluated at runtime according to the current values of some attributes and the features of the current instance (e.g. "*resource availability"*). Decisions that are based on dynamic CRK are taken into account at runtime. For instance: in the context of "*conflict of interest*", the actor "*John*" can not validate his/her proper loan request. Thus, in such a process intance, the assignement relationship of "*John*" to any role (e.g. "*loan handler*" allowing him to validate the loan request are disabled. However, the assignement relationship of "*John*" to the role "*Loan handler*" is still abled for the other process instances and processes.

In order to establish the most common contextual information which are relevant to, we propose a framework which encloses the following issues:

- **Who**: This issue copes with actors' and organisational units' properties such as *competency*, *experience*, *availablity*, *age*, *gender*, *coordination*, *communication*, *decision-making*, etc. Human related context attributes include *age*, *gender*, *experience*, etc. Some attributes are interrelated to the work (e.g. *motivation*, *ego involvment*, *job involvment*, *history*). Others reflect the relationship between actors: *actors hierarchically nearby*, *quality of communication* and *relationships between actors*, *collaboration sensitivity*. Organisation related context concerns the workplace characteristics, e.g. *relationship of the actor with his/her workplace*, *the kind of the organisational structure* (e.g. hierarchical, transversal), and the *cultural* and *social* aspects.
- **What**: This question concerns the material resources (business objects) properties such as *network connectivity*, *availability*, *data-sharing*, etc. Resources' properties include business objects characteristics (e.g. *resources availability*), as well as financial and time resources (e.g. *expensive operation*, *time consuming function*).
- **Why**: It concerns the business goals of the organisation.
- **How**: It concerns processes, activities and tasks properties for instance *security*, *confidentiality, repetitiveness, documentation* and *duration.*
- **When**: It reflects the features related to time. This may include performing time (e.g. *time in day*), *work duration*, *frequency*, *saving of time*, etc. These properties allow expressing business rules such as <The function *Loan Handling* can be handled by an actor which plays the role *Loan assistant* only in the context of *lack of resources* (e.g. if there is no free actors playing the role *Loan handler* and only if the process *time-to-finish* is less than 3 days)>.
- **Where**: It captures spacial properties like *location*. Note that the assignment of an actor to a role in a given process may depend on the specific area where the actor is working. Taking into account these properties allows expressing rules like: <Actors may be able to participate or not to a BP depending on their physical location>.

Note that the above mentioned set of context elements is not exhaustive and will be extended during our research.

B. Context Model for Business Process Modelling (CM4BPM)

Given the wide range of CRK, it is clear that a structure allowing the categorisation is required. Such structure will help application designers and developers to structure and manage context information and to use it efficiently. For this reason, we introduce a context model for BPM (*CM4BPM*) which is based on first-order predicate calculus. It covers a wide variety of available CRK and supports various operations, such as conjunction, disjunction, negation, and implication of contexts. It allows the creation of complex first order formulas involving context, so it is possible to write various business rules, and to evaluate queries. The CRK may be categorised from various aspects such as temporal aspect, location aspect, and so on. The proposed context model uses a two-dimensional space to describe the CRK.

The context is captured using facets which describe the non-functional features; each of them is addressed by some attributes. Attributes have values that are directly measurable.

The CRK can be represented using a structure of graph. We introduce the context tree for representing the CRK. The context tree is a two-level tree which root represents the global context, nodes refer to the facets and leaves refer to the attributes.

The construction of the context tree requires the competencies of the application domain expert. He/she has to collect and to structure the relevant context facets and attributes, to define the appropriate functions allowing measuring them. Note that some attributes of the context tree can be identified using the characteristics of the elements of the BP meta-model. For instance, "age" and "gender" are properties of the entity "actor", they can also be considered as leaves of the context tree. Context embedded in context tree nodes and leaves may act on the assignment relations linking the BP elements.

We assume that the context tree in this stage is appropriate to a particular application domain, for instance the banking field. Hence, this step is a first adaptation of the CRK to the organisation domain. The adaptation of the CRK to a given process is discussed in the following section.

Definition 2: *A Context Attribute* is an atomic feature making the CRK explicit. Its value might change dynamically (e.g. *date*), or vary from different instances of the same entity (e.g. *location*, *duration*).

At the implementation level, context attributes are represented by variables that are associated with specific domains of values to define the type and the range of values the context attribute may take. An example of domain of values may be *AVAILABILITIES*, type: *Boolean*.

Definition 3: A Context Function allows obtaining the current value of a given attribute. It can receive one or more parameters, for instance *experience(subject)* could be defined in order to return the current experience of a given subject. A context function may not receive any parameters (e.g. *day-of-week()*).

CRK is used to define situational assignment relationships. A situational assignment relationship is associated with one or more CRK and is activated only if each corresponding CRK is evaluated to "true". A CRK can be associated to one or more situational assignment relationships.

In the following, we define a set of check assignment predicates for context-aware instantiation decisions related to BPs.

```
// Assignment checking for actors to roles
check_actor-to-role_assignment_context(Actor, Role, crk):
    can_play(Actor, Role, crk)

// Assignment checking for roles to BPs
check_ role-to-BP_assignment _context(Role, BP, crk):
    participates(Role, BP, crk)

// Assignment checking for functions to roles
check_ role-to-function_assignment _context(Role, Function, crk):
    can_hold_context(Role, Function, crk)


// Assignment checking for actors to participate to BP
check_actor-to-BP_ assignment _context(Actor, BP, crk):
    check_actor-to-role_assignment_context(Actor, Role, crk),
    check_role-to-BP_ assignment _context(Role, BP, crk)

// Assignment checking for actors to perform functions
check_Actor-to-Function_Assignement_context (Actor,Function, crk):
    check_actor-to-role_assignment_context(Actor, Role, crk),
    check_ role-to-function_assignment _context(Role, Function, crk)
```

The check_assignment predicate verifies that a relationship can be activated or must be disabled. For instance, check_Actor-to-Function_Assignement_context checks that a relationship identified originally as (Actor, Role, Function) can be enabled in a current context. The predicates:

check_actor-to-role_assignment_context(Actor, Role, crk) and

check_ role-to-function_assignment _context(Role, Function, crk)

check, respectively, if the actor can play the role and if the role can hold the function in the context crk.

1) Atomic Context Model

We represent CRK through a first order predicate with four arguments: *Attribute Subject*, *Link* and *Value*. A CRK can be atomic or compound. An atomic CRK has the following structure.

$$CRK\,(ATTRIBUTE\,,SUBJECT\,,LINK\,,VALUE\,)$$

Atomic CRK can be used in order to construct more complex CRK by using for instance conjunction and negation operations.

ATTRIBUTE is the type of context defined by the predicate. *SUBJECT* refers to the thing with which the context is concerned. In the case of *internal* CRK, SUBJECT represents a process model element (e.g. an actor, an activity, etc.).

VALUE is a value associated with the subject, and LINK relates the subject and the value. The link can be preposition (e.g. *In, At*), a comparison operator (e.g. =, >), an adverb (e.g. *near*).

Examples for context predicates include:

$$CRK\,(Experience\,,Georges\,,>,5\,years\,) \quad (1)$$

$$CRK(Location, Georges, In, 90rueTolbiac - Paris) \quad (2)$$

$$CRK(Nearness, Georges, far - from, Maria) \quad (3)$$

The values of the SUBJECT and VALUE arguments depend on the value of the ATTRIBUTE argument. Thus, if the ATTRIBUTE is '*location*', then SUBJECT can be an actor or business object.

2) Complex Context Model

As context model is based on the first-order logic, it is possible to apply boolean operations and quantifications over atomic CRK predicates. Therefore, more complex CRK can be expressed. For example,

$$CRK\,(Lacation\,, Georges\,, In, 90rueTolbiac - Paris\,)$$

$$\wedge$$

$$CRK(Neeress, Georges, far - from, Maria)$$

states that '*Georges*' is in '*90rueTolbiac-Paris*' and that is far from '*Maria*'.

$$\neg CRK(Communication, Finance\_department, is, Available >$$

states that the '*communication*' between actors of the '*finance*' department is not '*available*'.

Therefore, CRK can be composed to form complex CRK. To be evaluated true, all the CRK included in a complex CRK must be evaluated true. The CRK can be stored in a context base.

C. Context parameterisation

The context can be parameterised by setting one or more arguments as variables of the CRK predicate. This can be done by using the qualification operators (i.e. universal and existential) over arguments. The existential quantifier signifies that the CRK is true for at least one value of the variable(s).

That is, $\exists x, x \in X, CRK(att, x, link, value)$ is true if and only if $CRK(att, x, link, value)$ is true for at least one value of x belonging to the set *X*. For example, $\exists x, x \in ACTORS, CRK(Experience, x, >, 5years)$ is true if and only if $CRK(Experience, x, >, 5years)$ is true for at least one value of *x* belonging to the set *ACTORS*.

The universal quantifier signifies that the CRK is true for all values of the variable.

Accordingly, $\forall x, x \in X, CRK(att, x, link, value)$ is true if and only if $CRK(att, x, link, value)$ is true for all values of x belonging to the set X. For example, to refer to all actors which experience is higher than five years, we express this predicate:

$$\forall x, x \in ACT, ACT \subset ACTORS, CRK(Experience, x, >, 5years)$$

By combining operators, one can easily express more complex and richer CRK.

Expressions are evaluated with quantifications which are done over specific domains of attributes. So, we define various sets of attributes (e.g. ACTORS, LOCATIONS, AVAILABILITIES, etc.). Each of these sets is finite, and we quantify variables over the values of one of these sets.

Accordingly, ACTORS consists of the set of the actors in the system. The set LOCATIONS contains all valid locations such as addresses, office numbers, etc.

The proposed context model, *CM4BPM* is based on the first-order logic, performing operations on context predicates. This allows us to express a large variety of CRK types (both simple and complex ones).

D. Context Related Knowledge Adaptation and Measurement

This issue concerns the question 3: "Which kind of contextual information can be relevant for a BP?" (c.f. IV). There are a lot of information expressing the context, however, in a given BP or focus, only a part of these information could present an interest for the required assignments. Accordingly, original context tree should be adapted so that, at a given time, it includes only contextual information which is relevant to a BP. The adapted context tree will include only meaningful aspects, facets and attributes for the given BP.

E. Context-Aware BP Instantiation

This issue relates to the selection of the best instances among a set of available ones with respect to the adapted context tree. This raises two main issues: (i) evaluation the adapted context tree and (ii) selecting the appropriate assignments to instantiate a BP based on adapted context tree.

- *ACT evaluation*: It raises two issues: (i) determining the significance of each context attribute and (ii) evaluating it. It is clear that all context attributes do not have the same relevance at a given time. We approach to associate weights to the attribute according to their importance. For example, in an urgent situation, matching the context attribute "*urgency*" is more significant than matching the context attribute "*competency*" or "*hour of the day*". Actually, CRK is diverse, some contexts are simple to measure/calculate (e.g. "*age*") and others are more difficult to qualify (e.g. "*competency*" or "*motivation*"). Determining how to measure the CRK is an important issue which requires more investigation.

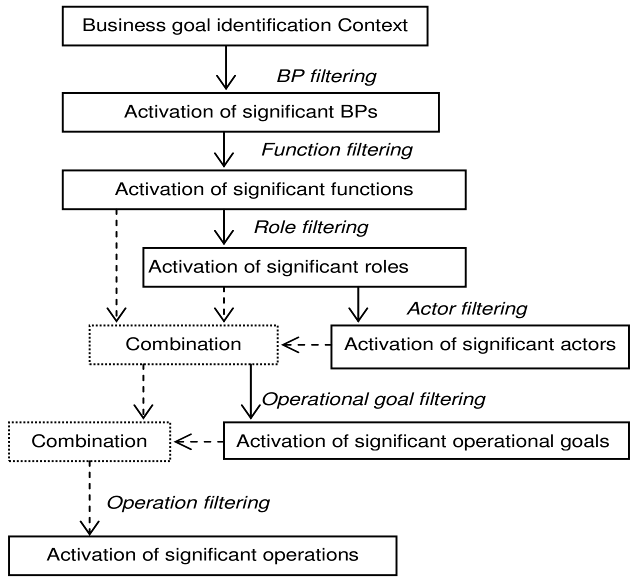

Figure 2. Procedure for BP instantiation

- *BP Instantiation*: in order to instantiate BP using the adapted context tree, we have introduced the concept *assignment activation* which means that only significant assignments have to be taken into consideration in a given context. Hence, the set of assignments which match better the current value of adapted context tree is activated. Assignments that are activated are those which variable values are included in the range of the adapted context tree current values. This requires identifying valid ranges of acceptable context values for every assignment type. Figure 2 resumes the different steps of the BP instantiation.

To deal with a dynamically changing context, assignment relationships can be rapidly modified according to the changes in the context.

Decisions on assignment activations are based on CRK. Actual values of the selected CRK are checked with respect to predefined situations. If these situations are satisfied, the corresponding assignment relationships can be activated. Thus, a relationship assignment is sensitive to one or more CRK.

F. Discussion

The support of the CRK requires four main steps. The first one relates to the context elicitation which allows to capture, to assemble, and to structure the contextual information. The second one is about the context categorisation using the context tree. The third step aims to adapt the CRK to a particular application domain and to measure it. The final step deals with the selection and activation of the appropriate instances of BP model entities and assignments.

The construction of the context tree is a complex task which requires the competencies of the application domain expert. He/she has to collect and to structure the relevant context aspects, facets and attributes. Afterwards, context values are determined based on the context tree. This is also done by an application domain expert. These administrative features are out of the scope of this paper and will be studied in our future work. BP enactment with respect to the context is a complex task which requires mechanisms for guiding the BP administrators to use correctly the CRK.

We addressed in this paper the relevance of the context related knowledge for adequate BP modelling. Context awareness allows business rules to be self-adaptive with respect to contextual circumstances. We believe that context sensitive BP models fit better the customers' expectations which are often context-dependant. From an administration point of view, context awareness enables BPs to be self-managing and automatic, minimising as a result administrator's guiding.

We discussed key issues related to the support of CRK including the elicitation of CRK, its categorisation, its adaptation, its measure and use for BP instantiation. We introduced a context model which captures most common CRK. We expect this model will evolve over time.

V. Conclusion

In this paper we have investigated the context related knowledge support for role-based BP modelling. We have previously introduced the role driven process meta-model (RBPM) and the concept of *function*, in addition to *role* and *operation*. The *function* concept is missing (except in OSSAD) in existing approaches that deal with *roles* as the ability to perform a set of *operations*. RBPM is a role driven approach for modelling flexible BPs. It has two major benefits:

- It offers flexibility in assigning functions to roles since a function can be performed by several possible roles according the performance context rather than a specific one,
- It gives to actors some autonomy allowing them to develop tactics for performing operations, operational goals and functions.

We proposed a context model which is flexible, so that it is possible to add new contextual characteristic at any time. We suggest adapting the context tree to specific BPs, we obtain thus the adapted context tree.

Context-awareness allows expressing a rich set of business rules and to adjust assignment activation and deactivation in a flexible way offering practical alternatives that depend on the context. It provides more appropriate matching so that only an actor which plays the appropriate role can perform an operation and only the suitable functions will be included in a given BP, etc. This ensures that BP instantiation matches actual usage and needs. Therefore, the context model offers the flexibility to activate assignments in specific BP instances. As well, a great amount of flexibility is brought by the concept of context. In fact, in current approaches, when changes related to the actor-to-role relationship happen, it seems necessary to modify some actor-to-role assignments according to the changes. Using contextual assignments allows assignments to be context-aware.

Our contribution presented in this paper offers a starting point for further investigations of context-based BP modelling. We identified a number of challenging issues that we wish to discuss in detail in our future works. We will be interested in particular to the issues related to:

- Context-oriented process patterns;
- Metrics for qualifying *CRK*. It must be underlined that actually most of the contextual information depends on the human interpretation.
- The dependency relationships between diverse context information and the use of these dependency relationships.

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