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A novel flexible activity refinement approach for improving workflow process flexibility

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ABSTRACT

Flexible activity refinement plays an important role in improving process flexibility and addressing uncertainties of business processes. However, it is still a challenge to refine flexible activities, and the existing researches on flexible activity refinement such as the refinement principles and methods, and their combination with factors such as constraints and contexts is still lacking. Aiming at this, a novel dynamic refinement approach for flexible activities is proposed, which combines both vertical decomposition and horizontal extension refinements, with the impact of constraints and contexts considered. In particular, we summarize five typical refinement categories, and present a set of activity refinement rules based on them. Furthermore, the decomposition refinement, including the activity decomposition principles, the related rules for trigger event delivering and execution condition transferring is discussed in detail. The extension refinement, which realizes the horizontal refinement, can be integrated with other kinds of refinement and uses constraints to specify activity selection, activity temporal relationships, etc. Then, a tree-like activity refinement graph (ARG) is proposed to represent the refinement process, based on which the refinement cost and refinement degree can be computed to benefit the finding of the potential optimal refinement path. As a further implementation of the proposed refinement approach, a general refinement algorithm is described. Finally, a case study of urolithiasis therapy process and its application are given, and the results indicate the effectiveness of our proposals.

1. Introduction

Workflow management has been widely adopted as a core technology to manage long-term and complex application processes in many fields [1]. A process model defines a business process and determines the way the process instances are handled. It can be specified, in imperative approaches, by a detailed step-by-step procedure that should be followed during the execution, or by a more flexible expression form such as constraint-based rules [2,3]. Actually, static and non-flexible process descriptions are more suitable for invariant traditional business processes but not dynamic and complex ones. The inherent complexity and uncertainty of business processes often bring enormous difficulties for the modeling and applications of workflows. It is difficult to cover all the uncertainties in the modeling stage and if so, it may lead to over-specification problems. So how to deal with such uncertainties and to improve process flexibility has drawn increasingly considerable attention from researchers [4–7].

Dynamic refinement is an effective way to respond to the uncertainty and variability of business processes [4,8]. Unlike other kinds of process flexibilities [4,8] such as dynamic deviations, dynamic selections, and dynamic changes, which always emphasize the modification of an existing process model to change its procedure (always a well defined one), it emphasizes the transformation of a process model into a more specific process description by providing a concrete realization for the undefined parts. Its main characteristics include using a core process to represent the frame and specified parts of a business process, while the undetermined and ambiguous parts can be modeled as a flexible activity (or a placeholder) which needs to be refined gradually later after obtaining sufficient modeling information during the execution [9–11]. For example, a therapy activity in a medical process can not be specified in advance, because it varies on different individuals and contexts. Hence it can be defined as a

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flexible activity and its refinement will be deferred to runtime. In this procedure, the refined process should refer to the intended behaviors of the abstract process and satisfies related constraints [12].

Recent approaches on dynamic refinement mostly focused on vertical decomposition nature of activities [4,13,14], where an abstract activity can be divided into several smaller while more specific activities. So the achievement of the goal of the abstract activity can be realized by achieving all the goals of its decomposed sub-activities. Li et al. [13] adopts product tree to facilitate the understanding of the vertical relationships among activities, and the hierarchical relationships among products are similar to those of activities. The dynamic refinement of activities is performed by mapping from the product tree to process templates. In the Activity Theory [15], activities are considered as hierarchical (consist of one or more actions), contextual, and dynamic, etc. These findings naturally inspire us to develop a refinement approach supporting hierarchical decomposition and addressing contextual and dynamic issues. However, the existing approaches such as Worklet [11], Pockets [9], product tree [13], etc., devoted few efforts into the investigation of the definition, principle and methods of the vertical decomposition, which could be guidance for performing an effective and proper decomposition, and thus are critical to dynamic refinements.

Another research trend in dynamic refinement is the constraint-based declarative approaches, tending to describe all the activities of the process model and the main constraints describing the relationships among these activities [3,16]. There are no explicitly defined execution paths as all the possibilities of them are allowed if only they do not violate the constraints, e.g., DECLARE [3], ConDec [16]. However, these approaches are not good at precisely describing the procedure of process models, so they need to work together with imperative approaches. Furthermore, the activity refinement is always a dynamic process of transforming unspecified parts of the model into well-defined parts by providing more concrete realization, which put forward a higher demand of application of constraints. During this process, the usage of constraints should be extended accordingly to guide the refinement process, e.g., specifying the activity selection, activity properties and temporal relationships adjustment, etc., and the integration with imperative methods should also be taken into account.

With respect to the essence of an activity refinement, besides the refinement along the vertical direction (i.e., decomposition operations), the horizontal extension of an activity is also necessary for the refinement. Research on this field should address the problems: 1) the selection of activities, their ordering relationships, etc., and the related constraints; 2) the refinement type, such as fully automated support, partially automated support, and manual control. The manual control type allows an activity to be built from scratch. Though much progress has been made in this field, the investigations of combining both these two aspects to make the refinement more effective and flexible are still ignored.

To overcome the limitations of the approaches mentioned above, we proposed an innovative dynamic refinement approach of flexible activity, which takes the advantage of both the vertical decomposition and the horizontal extension refinements, and combines constraints and contexts with the approach. The main contributes of this work can be described as:

1) We provide a comprehensive categorization of refinement characteristics for flexible activities, based on which the refinement rules and principles are explored. ARG is proposed to represent the refinement process, and the computation of refinement cost and degree is also described. All these aim to provide a systematic way for flexible activity refinement to address the dynamics and uncertainties of processes, and to improve the process flexibility.
2) Incorporating constraints and contexts into the proposed refinement approach will endow the system with certain process-aware capability to generate a better refined activity by filtering undesired candidates. Constraints are also used for the validation of the generated sub-process.
3) The proposed approach combines the vertical decomposition and horizontal refinement (and more other kinds of refinements as its openness), and integrates constraints and contexts in activity selection, temporal relationship determination and validation.
4) As a further implementation of the proposed refinement approach, a general activity refinement algorithm is presented, and the results of the application indicate the effectiveness of our proposals.

The paper is organized as follows. In the next section, we describe the theory for flexible activity refinement. Section 3 describes an overview of our integrated refinement approach with the detailed discussion of the decomposing and functional refinement. Section 4 introduces the representation of activity refinement process and the computation of refinement cost. In Section 5, we describe the implementation of the approach and a case study. Finally, we discuss related work (Section 6), and summarize our work (Section 7).

2. Theory for flexible activity refinement

2.1. Activity refinement and categories

Definition 1 (flexible activity). A flexible activity can be regarded as a special activity that can not be specified clearly in advance due to the vague and lacking process information. It can be specified gradually and fully after obtaining enough desired process information. A flexible activity can be denoted as: $FA = (Obj, f{:}\delta \rightarrow \gamma, FAP, FAR, FAC, Props, Roles)$, where *Obj* is used to describe the objective of the activity as well as the application scenarios, and *f* is a function to convert the input information δ to the output information γ to achieve the goal of the activity. $FAP = A_{atom} \cup A_{comp} \cup A_{flex}$ is an activity pool, which consists of atom activities, composite activities and other flexible activities. A composite activity is a well-defined activity contains several sub-activities without vague specifications. *FAR* is the rule set (and can be null) used to describe the relationships among activities in the activity pool. $FAC = C \cup M$ is a constraint rule set, used for storing the constraints that should be fulfilled during the refinement process. Herein, *C* is the constraint rules for specifying the selection and combination of activities, their execution order, and the properties. *M* is the adjustment rule set, used to modify the generated sub-process.

A flexible activity should be refined before its execution though this is always difficult. Such a refinement process can be viewed as a state transition process under the operation of refining functions, i.e., from an initial refinement state A_0 to the terminal state A_T, which forms a state sequence: $A_0 \rightarrow A_1 \rightarrow \ \ldots\ \ldots\ \rightarrow A_T$. It is a gradual refinement process, from vague to determined, and also from coarse to fine-grained in granularity. However, the characteristics of activity refinements carried out in different manners as well as their categories should be investigated, which may give an insight into how the refinement of flexible activity progresses and thus may facilitate the implementation of activity refinements. We group the activity refinements into several categories according to their characteristics: decomposition refinement, functional