Deriving user interface flow models for artifact-centric business processes

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\textbf{ABSTRACT}

Artifact-centric business process modeling is emerging as a promising paradigm for modeling data-intensive business processes as it provides higher flexibility and extensibility support in comparison to the traditional activity-centric modeling paradigm. Several approaches exist on (semi-) automatically generating user interface (UI) models for activity-centric processes. However, little work has been done on generating UI models for artifact-centric processes. In this paper, we propose a framework for deriving user-interface flow models to help visualize artifact-centric processes and support semi-automatic creation of UIs. The UI model is created by taking into account the relationships among business processes, user interfaces, and user roles in an artifact-centric process model. Algorithms are also developed to derive UI flow models from an artifact-centric process model. We have conducted experiments and implemented a prototype system to prove our concept and evaluate the feasibility and technical performance of our approach.

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1. Introduction

Nowadays, with the business focus shifting from products to customers, businesses concentrate more on how their business operations can be efficiently organized so as to better deliver business value to their customers and thrive in the market. Business strategies can be operationalized and implemented by means of business processes, which are coordinated activities executed by stakeholders in order to provide services to customers. Therefore, business processes have turned out to be one of the most important aspects that leverage businesses in a competitive market. Business process modelling is the method for representing a business process in an intelligible format (e.g., graphical notation). A business process model is an essential tool for businesses to formulate and reason about how desired business goals are achieved, and serves as an effective communication median among business stakeholders. In general, a business process model describes how activities are performed (by organizational resources – which can be humans or automated systems) in order to achieve business goals.

In recent years, businesses are forced by economic constraints and competitive business environments; therefore, they seek for an innovative improvement of their business operations to outperform their competitors. Apart from that, businesses have often grown from mergers and acquisitions, which leads to redundancies and inconsistencies of operations and processes. The traditional workflow modeling approach turns out to be increasingly difficult to implement because business processes become more sophisticated and larger in size \cite{29}. This brings in challenges to the modeling, design, and management of complex and dynamic requirements of business processes. As such, a business process model should not only be used to ensure that the work can be completed as desired but also to facilitate operational innovation and cost saving. A traditional business process (or workflow) modeling approach (e.g., Business Process Modeling Notation (BPMN) \cite{2}, Business Process Execution Language (BPEL) \cite{1}, Event-driven Process Chains (EPC) \cite{3}, and Yet Another Workflow Language (YAWL) \cite{4}) emphasizes on the sequencing of activities (i.e., control flows) in a process as a first-class citizen. However, it pays less attention to data aspects of business processes. Many
Process-Aware Information Systems (PAISs) provide capability to define a data model associated with a task of a business process; however, such data models are specified on top of the activity-based models and they are logically detached from the activity-based models. As there is a lack of a holistic view of data information and activity contexts, business actors and process modelers are often riveted by what should be done instead of what can be done. This can result in hindering operational innovations since it is difficult to comprehend the possible effects of the sequence of processing steps on key business entities [3–8]. In addition, as constructing processes with sequenced activities leads to tightly coupled process structures, process componentization and extension are difficult to be achieved in a natural way [9].

In the past several years, a new approach to modeling business processes has emerged – that is **artifact-centric (operational) business process modeling** [10]. Rather than primarily focusing on the activity flows of a business process, the artifact-centric approach focuses on key business-relevant entities that evolve as they progress through the operations of the process. This approach enables a natural modularity and componentization of business operations and at various levels of abstraction [11]. It provides an intuitively natural, robust, and flexible structure for understanding and specifying business processes and operations in four explicit, inter-related, but separable dimensions in the specification of business processes – which are *business artifacts*, lifecycle of artifact, services (a.k.a. tasks), and associations (between artifacts and services) [12]. Artifacts integrate both data aspects and process aspects into a holistic unit, and serve as basic building blocks in a process model. The (macro) lifecycle of an artifact is described in terms of “business stages” and the possible evolution of the artifact. The specification of how artifacts are involved and how services operate on them is described in terms of their associations, which can be expressed in a declarative manner (e.g., Event-Condition-Action (ECA)-styled business rules).

However, expressing business process logic by using declarative business rules makes process modellers difficult to see and understand the structure and flow of the process, especially when a business process is distributed in a complex, intra-organizational environment. In the user-centric aspect, this brings in a key challenge to have a natural approach for representing such declarative process models to non-technical stakeholders, such as business analysts and process managers [12,15,16,51,52]. There should be a more natural way to support them in order for them to better comprehend artifact-centric process models from both process flows and process data perspectives.

From the viewpoint of end users, user-interfaces (UIs) are designed to allow and help users interact with a process managed by a process-aware information system. By having a closer look at artifacts and user-interfaces, we can see that on the one hand a user-interface is used for users to view/input business artifact data and invoke a related function that affects the process; on the other hand, the artifact data and business rules decide which user-interface should be brought for the users to fulfill a certain procedure of the process. Therefore, the data inputs and navigation flows of UIs can be used for representing (or visualizing) an artifact-centric process model in a task-based/control-flow structure. Apart from the representation benefit, UI developers or application developers can use these UI models for generating actual UIs (e.g., Web pages) for artifact-centric business processes. As such, we can see that the benefit of deriving UI models is twofold: visualizing business processes and supporting the development of process-given UIs. However, there are some approaches (e.g., in [20,23,48,49,50]) proposed to automatically generate UIs from an artifact/data-centric process models, where the set of generated UIs needs to present both control and data aspects of a business process. Due to the distribution of process specifications across various organizational units and departments, the UIs generation should also support different roles of users in different organizational units that participate in the business process. In addition, the generated UIs should be further customized by UI modelers without concerning the integrity of business logic, and changes of data requirements specified in the model should be automatically reflected on UIs. Therefore, in this article we study the interplay between UIs and artifact-centric process modeling and propose a framework that can help organizations meet the aforementioned requirements for UI generation, which can be used for visualizing business processes as well as for facilitating the implementation of concrete user interfaces for complex and collaborative business processes. We have previously introduced a model for an artifact-centric business process with a preliminarily model for capturing user interfaces in our previous work [27,45]. Therefore, our research extends those work and includes the following contributions.

- We propose a UI derivation framework that consists of a user interface flow (UIF) model, a well-formedness property, and theorems to support a sound derivation of UIs from an underlying business process model. The UIF model is a conceptual model used to represent the logical structure of user interfaces and their interaction flows. It provides an intuitive process structure, likewise an activity (control-flow) structure, for artifact-centric models, which helps process modellers and non-technical stakeholders who are interested in the process to easily understand the flow of a process.
- We design related algorithms that automatically derive a UIF model and a UIF-role model from an artifact-centric process model. The algorithms are also guaranteed the well-formedness and the consistency between the generated UIs and their underlying process model.
- We develop a system prototype and perform a set of experiments to evaluate the feasibility and scalability of our framework. The UIF models generated from the prototype are serialized in an XML format, and therefore, it can be used as the skeleton for generating actual HTML Web pages via the use of XSLT and CSS design templates. Our experiment results show that our system can take up to quadratic time $\Theta(n^2)$ in run-time if performed on a single computing machine.

The remainder of this article is organized as follows. Section 2 briefly discusses the motivation of the artifact-centric approach to modeling business processes as the background of our work and then presents a motivating example, which will be referred to throughout this paper. Section 3 presents our UI derivation framework for artifact-centric business processes. Section 4 evaluates the feasibility of our framework based on our proof-of-concept prototype implementation and experimental study. Section 5 discusses related work. Lastly, conclusion and future work are presented in Section 6.

### 2. Background and motivating example

Nigam and Caswell [10] firstly introduced the concept of modeling business processes from business artifacts and their lifecycles. A *business artifact* (or *artifact for short*) is defined as a concrete, identifiable, self-describing chunk of information that can be used by a businessperson to actually run a business. Artifacts can be referred as business records and have to be recognizable, i.e., to contain information in one place, and are taken to be the only explicit information contained in the business, i.e., a set of business records that represent the content of the business.
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