A Methodology for the Design, Verification, and Validation of Business Processes in B2B Collaborations

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1 Introduction

The modeling of collaborative business processes is a key issue in order to allow enterprises to implement Business-to-Business (B2B) collaborations. A *collaborative business process* defines the global view of interactions among enterprises to achieve common business goals and coordinate their actions [3]. The development of a B2B Collaboration implies the definition of a business solution and a technological solution. The *business solution* implies the design of collaborative processes in order to define the behavior of the inter-enterprise collaboration, whereas the *technological solution* refers to the generation of B2B specifications and the implementation of information systems of the enterprises to execute collaborative processes.

Models of collaborative processes are used as design artifacts to describe the business solution of a B2B collaboration. They are designed from a business perspective by business analysts and system designers. Hence, collaborative process models should be defined independently of any implementation technology. The use of these models enables the automatic generation of B2B specifications. In previous work, the model-driven development's principles [4] and the Model-Driven Architecture (MDA) [1] were identified as key enablers to support the modeling and specification of collaborative business processes [2].

With the aim of ensuring that the collaborative processes are error-free and they meet the objectives and goals of the B2B collaboration, the application of verification and validation methods for collaborative process models is required. Therefore, the research topics of this work are *design*, *verification* and *validation* of collaborative business process models in B2B collaborations.

2 Identified problems and current solutions

An MDA-based method for the design of collaborative processes and the automatic generation of B2B specifications was proposed in [2, 3]. In this method, the UML Profile for Collaborative Business Processes based on Interaction Protocols (UP-ColBPIP) was defined. This language supports the modeling of technology-

independent collaborative processes and fulfills the requirements of B2B collaborations: enterprise autonomy, decentralized management, peer-to-peer interactions and negotiations. The UP-ColBPIP language proposes modeling the behavior of collaborative processes through interaction protocols. An interaction protocol is a choreography of messages between the participants. Each message is described by a speech act, which represents the intention the sender has with respect to the information exchanged in the message.

As part of this MDA-based method, model transformations to support the automatic generation of technological solutions, based on different B2B standards, were defined. In particular, transformations from UP-ColBPIP models into ebXML-based specifications [5], BPEL-based Web Service compositions [6], and Web Service choreographies based on WS-CDL [7] have been defined. By applying this method, B2B specifications (i.e. the technological solution) are guaranteed to be aligned with the business logic defined in collaborative process models (i.e. the business solution), because B2B specifications are automatically generated from collaborative process models.

The use of technology-independent models to verify system's properties at early stages of development has been recognized as one of the main aspects to be supported by a model-driven method [4]. Since it is at these stages of the development when business analysts and system designers make most of the fundamental decisions and, in addition, since collaborative process models describe the behavior of the interactions between enterprises in B2B collaborations as well as the way in which the enterprises' systems will interact, the *verification* and *validation* of these models are a main issue in order to guarantee enterprises that the behavior of a B2B collaboration is well-defined and error-free. Therefore, the verification and validation of collaborative process models enhance the benefits and functionalities of MDA-based methods for the modeling and specification of collaborative processes.

Verification is the task of checking that a model matches a given specification [8]. There are different proposals to verify B2B process specifications based on technology-specific languages such as BPEL [10] and WS-CDL [11]. The main drawback of these approaches is that they are focused on verifying process specifications when the technological solution has already been generated. In [17], it is described an approach for a static analysis of global models to detect errors, such as unreachable interactions, but this language provides a particular notation instead of a well-known notation, such as UML. Other languages for collaborative processes, such as UMM [18], do not provide a verification approach.

The verification approach can be added to the UP-ColBPIP language. Since UP-ColBPIP is a semi-formal language based on the UML semantics, the formalization of interaction protocol models which represent the behavior of collaborative processes is necessary to support the verification approach. Through formalization of the UP-ColBPIP language, a semantics without ambiguity can be provided for the primitives used to model interaction protocols.

Although collaborative process verification guarantees error-free processes, this is not enough to determine if the collaborative process logic behaves as expected by business analysts. To achieve this, a validation approach should be applied. Validation is the task of checking whether a model or system fulfills the expectations of the user, customer, or client [8]. At present, there are a few techniques and tools

that support business process validation in B2B environments. In [12], an ontology-based method to semantically assist in the design of business processes is presented. In [13], an approach for the analysis of collaborative processes by means of Petri Nets is described. But they just focus on performance measures omitting the validation if the process logic is aligned with the business requirements of the B2B collaboration.

Finally, the verification and validation should be applied on modeling languages with a complete set of control flow constructors to define collaborative processes. Workflow patterns can be used to evaluate the expressiveness of business process languages. The UP-ColBPIP language was evaluated with the workflow patterns. Although most of the main control flow constructors are provided by this language, it does not have structures that allow the modeling of multiple instances and advanced control flow synchronization patterns. Therefore, the incorporation of new control flow constructors to the UP-ColBPIP language is required.

3 Proposed solutions and expected contributions

The aim of this research is the development of a methodology providing methods, techniques and tools for the design, formal specification, verification and validation of business processes involved in a B2B collaboration. In order to achieve this, the proposed solutions are described.

(1) Extension of the UP-ColBPIP language with new primitives in order to provide a complete set of constructors to model interaction protocols. In particular, new control flow constructors for representing multiple instances and advanced control flow synchronizations are added.

(2) Formalization of the primitives of the UP-ColBPIP language by using Hierarchical Colored Petri Nets [8]. For each primitive a CP-Net pattern representing its formal semantics from the viewpoint of the control flow is defined. The CP-Net patterns are used to build hierarchical CP-Nets representing interaction protocols. This formalism allows verifying the correctness of collaborative processes and the structural verification of interaction protocols.

(3) An MDA method for carrying out the automated verification of collaborative process models at an early stage of the development is proposed. This method provides model transformations for generating hierarchical CP-Nets specifications from UP-ColBPIP models, by using the above CP-Net patterns [9]. CP-Nets specifications are generated according to the XML-based format used by CPN Tools [7]. Thus, behavioral properties of CP-Nets representing interaction protocols are verified by using techniques provided by CPN Tools. Relevant properties of a CP-Net for the verification of interaction protocols were identified in order to perform the automatic interpretation of the results generated by CPN Tools and to indicate the errors in the interaction protocols defined with the UP-ColBPIP language.

(4) A validation method to enable the validation of collaborative processes, which considers three different viewpoints of a validation, is proposed:

- A validation of the interaction protocol semantics. This means the determination of inconsistencies in the message choreography by analyzing the semantics of the speech acts used in the messages. The receiver of a message should respond

with an appropriate speech act, according to the semantics of the speech act associated with the received message. To reach this, an ontology for interaction protocols is proposed that describes the semantics and relationships of the speech acts along with different control flow constructors of the protocols.

- Validation of the alignment of business objectives and requirements of a B2B collaboration with the behavior defined in collaborative processes. The purpose is to determine the inconsistencies of the defined collaborative processes with respect to the expected business logic of the B2B collaboration. To do that, the use or extension of a high-level abstract language for modeling business requirements and goals, such as I* [14] or e^3value [15], will be evaluated. In addition, relationships between concepts of the business goal language and the UP-ColBPIP language will be defined in order to propose a validation process that allows business analysts to know if the business logic of collaborative processes is aligned with the goals of the B2B collaboration.
- Simulation of collaborative processes with the purpose of enabling performance analysis (such as bottlenecks, average completion time, and so on) and the evaluation of key performance indicators defined on collaborative processes to determine if they achieve their goals. To reach this, interaction protocols are transformed in Time Colored Petri Nets [8]. This is carried out by adding time specifications to a generated CP-Net that represents an interaction protocol.

To support the above validation processes, an MDA-based method is proposed in order to generate the Time CP-Nets as well as the instantiation of the ontology of the interaction protocols, from a UP-ColBPIP model.

(5) Finally, the contributions of this work will be incorporated to an Integrated Development Environment (IDE) based on Eclipse for the model-driven development of collaborative processes [16]. Currently, this tool has a set of Eclipse plugins that were developed to support the UP-ColBPIP language and automate the MDA-based method that generates the CP-Nets of interaction protocols for verification. This IDE will allow the implementation of case studies and will serve as a tool to carry out the evaluation of this contributions and proposal of this research.

4 Results and evaluation method

The main expected results of this research work are:

- An MDA-based method that supports the *verification* of collaborative processes, so that structural problems can be detected at an early stage of the development.
- An MDA-based method that supports the *validation* of collaborative processes, so that semantic inconsistencies as well as performance problems within these processes can be detected at an early stage of the development.
- An Integrated Development Environment that implements the proposed MDA-based methods and supports the automated *verification* and *validation* of collaborative business processes.

The evaluation and validation of the MDA-based methods proposed in this work will be carried out through an empirical research of case studies. Such case studies will be developed into the Eclipse-based IDE for collaborative processes in order to carry out

and facilitate the evaluation of the MDA-based methods. In addition, these methods will be compared with other approaches using the same case studies.

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