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A formal approach to modeling and verification of business process collaborations

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ABSTRACT

In the last years we are observing a growing interest in verification of business process models that, despite their lack of formal characterization, are widely adopted in industry and academia. To this aim, a formalization of the execution semantics of business process modeling languages is essential. In this paper, we focus on the OMG standard BPMN 2.0. Specifically, we provide a direct formalization of its semantics in terms of Labeled Transition Systems. This approach permits to avoid possible miss-interpretations, due to the usage of the natural language in the standard specification, and to overcome issues due to the mapping of BPMN to other formal languages, which are equipped with their own semantics. Our operational semantics is given for a relevant subset of BPMN elements focusing on the capability to model collaborations among organizations via message exchange. One of its distinctive aspects is the suitability to model business processes with arbitrary topology. This allows designers to freely specify their processes according to the reality, without the limitation of defining well-structured models. The provided formalization is also implemented by exploiting the capabilities of Maude. This implementation takes a collaboration model as an input and, explores all the model executions. By relying on it, automatic verification of properties related to collaborations has been carried out via the Maude model checker. We illustrate the benefits of our approach by means of a simple, yet realistic, running example concerning a travel booking scenario.

1. Introduction

For some years now, complex organizations recognized the importance of having tools to model the different and inter-related aspects governing their behavior. Among the different perspectives, used to model organizations, and summarized for instance in the Zachman's framework [1], particularly relevant is certainly the description of how the activities are structured in order to reach the organization objectives. This point of view is generally reflected in a Business Process (BP) model that is characterized as "*a collection of related and structured activities undertaken by one or more organizations in order to pursue some particular goal. [...] BPs are often interrelated since the execution of a BP often results in the activation of related BPs within the same or other organizations*" [2].

Different languages and graphical notations have been proposed to represent BP models with differences in the level of formality used to define the notation elements. BPMN 2.0,[1] which has been standardized by OMG [3], is currently acquiring

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[1] We use BPMN or BPMN 2.0 interchangeably to refer to version 2.0 of the notation.

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a clear predominance among the various proposal, due to the intuitive graphical notation, the acceptance by industry and academia, and the support provided by a wide spectrum of modeling tools.[2]

BPMN success comes from its versatility and capability to represent BPs for different purposes. The notation acquired, at first, acceptance among business analysts and operators, who use it to design BP models and mainly for communicative purposes. Successively, it has been more and more adopted by IT specialists to lead the development and settlement of IT systems supporting the execution of a specified BP model. This shift in the usage of the notation is particularly relevant and poses the basis for our work. Indeed the OMG standard does not provide a precise definition for the semantics of the notation. The lack of a precise semantics may not represent a big issue when the notation is used just for communicative purposes. Instead its adoption for shaping IT systems, and even more to apply model driven approaches to code generation, does require the definition of a precise semantics enabling also the introduction of formal verification strategies.

Among the various characteristics of BPMN particularly interesting is the possibility to model *collaborations* involving different organizations, exchanging messages and cooperating to reach a shared objective. Collaboration diagrams are the focus of our work. Such diagrams contain enough information to assess the alignment of participants behavior with respect to the message flow, so to permit a successful cooperation. In this case the definition of a precise semantics has probably even more important consequences, given that collaborations among organizations are more and more mediated through IT systems, according for instance to the Service-Oriented Computing paradigm. In fact, when a modeling notation is used in a homogeneous context, such as a single organization, the precise definition of the meaning of the various elements constituting the notation can be sometime overlooked. Nevertheless mutual understanding is still possible thanks to the direct communications among the involved stakeholders, and from the emergence of established and accepted practices. This cannot be the case when two or more organizations are involved. In fact, in order to correctly collaborate, different organizations have to share the same understanding of the communication flow, in particular when this has to be supported by software systems.

In defining the notation, OMG did not intend to provide a rigorous semantics for the various graphical elements; instead the meaning is given using natural language descriptions. However, the use of formal tools to define the semantics of the various elements, and hence of a BP model, is required to enable automatic analysis activities. This aspect seems to be even more relevant when organizations get in contact with each other and they need to analyze the impact of collaborative actions. Consider for instance the merging of two companies in which there is not a common understanding of the meaning and effect of the activities within a process. In this case a precise semantics of the collaboration model is crucial to favor a more seamless integration, by also enabling analysis activities aimed at discovering possible flaws in the collaboration. In fact, a BPMN model is a complex artefact that can include many errors difficult to spot by humans. To tackle this issue we propose a verification approach able to spot both errors due to internal behavior of a participating process, and errors due to interaction among the participants (e.g., protocol mismatch).

In the last years, a relevant effort has been devoted by the research community to provide a formal semantics to the BPMN notation (we refer to Section 7 for a wide overview of major contributions on the subject). In this paper, we intend to contribute to such a research effort aiming at providing a precise characterization of a subset of BPMN elements largely used in practice. In selecting the BPMN elements to be included in our formalization, we follow a pragmatic approach. On the one hand, to keep the considered fragment of the language manageable (to have, e.g., a simpler formal semantics), we only retain the core features of BPMN. However, even if we focus on a restricted number of elements, we do not consider such design choice a major limitation of the work. Indeed, despite the BPMN specification is quite wide, only less than 20% of its vocabulary is used regularly in designing BP models [4]. On the other hand, we deal with elements concerning collaborations, which are overlooked by other formalization proposals, as they typically focus only on process elements. Our special emphasis on communication aspects within collaboration diagrams is mainly motivated by the need of achieving inter-organizational correctness, which is still a challenge [5]. Notably, the approach we propose here does not aim at checking that a participant is able to enter a prescriptive interaction scenario (generally referred as a choreography). Instead, it intends to support the checking that a collection of processes are actually able to correctly interact when integrated all-together (e.g., absence of deadlock situations due to lack of expected messages, or capability of processing all produced messages).

Our formalization also includes the management of termination end events, used as opportunities to quickly abort processes. This feature is usually not supported in other approaches, especially those based on Petri Nets [6]. Indeed, while for the basic BPMN modeling elements the encoding in Petri Nets is rather straightforward, defining an encoding for terminating events is quite difficult. This is due to the inherent complexity of managing non-local propagation of tokens in Petri Nets, which instead is supported by our semantics.

Differently from other proposals, we do not impose any syntactical restriction on the usage of the modeling notation, such as *well-structuredness* (which, roughly, imposes gateways in a process to form single-entry–single-exit fragments). Even though our semantics works and enables analysis for well-structured models, we refer here to process models with an arbitrary topology. Well aware of costs and benefits of the structuredness in process modeling [7], we aim at removing such restriction to allow more flexibility for BP modelers. Indeed, well-structuredness per se does not guarantee that models are correct (e.g., sound [8]), but it is just a way to contribute to solve some modeling issues [9]. Structuredness restrictions,

[2] BPMN is currently supported by more than 70 tools (see http://www.bpmn.org for a detailed list).