Business Process Analysis

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INTRODUCTION

Business-process management (BPM) is nowadays a key technology for the automation and support of processes in medium-sized and large organizations. This technology has been successfully applied to business-to-consumer (B2C) and business-to-business (B2B) e-commerce since the '90s, and it is now being applied also in e-government for the management of administrative procedures. As stated in Aalst, Hofstede, and Weske (2003), the origins of BPM technologies can be found in the '70s with the research on office information systems. Research in this area was almost stopped in the '80s, but it rose again in the '90s under the name of work-flow management. Now it is evolving with a more integral approach and a new name: BPM. It is defined in Aalst, Hofstede, and Weske (2003, p. 4) as "supporting business processes using methods, techniques, and software to design, enact, control, and analyze operational processes involving humans, organizations, applications, documents and other sources of information." The main functionalities provided by a BPM system are defining business processes, automatically enacting them, controlling their enactment, and analyzing them. This article is focused on the last functionality: business-process analysis (BPA).

BPA can be defined as a set of technologies that provide support for obtaining relevant properties of business-process models in order to reason about them, detect functional errors, or improve their performance.

BPA was a neglected area in the work-flow management systems developed in the '90s. Will van der Aalst (1998) was one of the first researchers in this field. He proposed the use of petri nets for modeling business processes and the application of the analysis theory developed for this formalism to demonstrate the correctness of the developed processes, analyze performance, and so forth. Since then, other approaches, based on formal methods, were proposed. BPA is important for BPM because it provides the technology for improving the reliability and efficiency of the business process of organizations. Reliability considerably reduces expenses caused by errors in transactions. Efficiency reduces expenses caused by an inefficient use of resources and can improve the satisfaction of customers.

The next section provides a background on the most important analysis technologies: functional verification and performance measuring. Then, the discussion is focused on functional verification. An overview on how different authors applied functional verification to business processes is presented. Then these works are analyzed and an open, modular, and extensible architecture for the functional verification of business processes is presented. Later, the future trends on this topic are outlined. Finally, the conclusion highlights the main concepts introduced in this article.

BACKGROUND

BPA technologies help process designers to reason about process models in order to guarantee a desired level of quality. The objectives of BPA can be classified into two main groups: functional verification and performance measuring. Functional verification consists of checking if the process is consistent with its functional requirements; that is, the process does always what it is supposed to do. Results of this type of analysis are used to correct functional errors in process models. Performance measuring consists of obtaining statistics about the performance of the process from the point of view of the customer (response times) or from the point of view of the organization that performs it (usage of resources). Results of this type of analysis can be used to obtain statistics, or to identify parts of the models that should be reengineered in order to improve performance. Depending on the type of reasoning needed, different analysis techniques are used. They are normally adapted from other fields like computer science. This section provides an overview of some of these techniques and shows how they are being applied for analyzing business processes.

Functional verification is an active area of research that is being applied to different fields, such as software engineering, digital-circuits design, or protocol design. As stated in Clarke, Grumberg, and Peled (1999), the main

techniques for functional verification are guided simulation, testing, deductive verification, and model checking.

Performance analysis is used, for example, for designing telecommunication networks, operating systems, or manufacturing processes. Techniques for performance analysis are normally based on queuing theory and simulation (Gross, 1998).

Guided simulation and testing are two traditional and widely used approaches for verification. Guided simulation is performed by executing the process model in a fictitious environment provided by a simulator. The designer can, for example, guide the simulation, view or modify the content of variables, or put break points into the process definition. Testing consists of checking the correct behavior of the process in the real business-process management system before its definitive deployment. Although they are very useful analysis techniques, simulation and testing cannot, in general, analyze the behavior of all the possible execution traces of a process. In addition, they require too much human intervention and cannot be automated.

Deductive verification and model checking are techniques based on formal methods. They can be used to prove that a given property is true (or false) for every possible evolution of a process model.

Deductive verification is based on the use of mathematical axioms and rules for proving properties of models with the assistance of semiautomatic theorem provers. Deductive verification can be used to prove properties even in infinite-state process models. However, its main disadvantages are that it must be performed by trained experts, it requires a large amount of time, and it is an error-prone technique (Wang, Hidvégi, Bailey, & Whinston, 2000). These problems could be solved in the future with the development of more powerful theorem-proving algorithms. Formalisms like Z (Spivey, 1992), the B method (Abrial, 1996), or VDM (Jones, 1990) can be used for this purpose.

Model checking is a powerful technique for automatically verifying finite-state, concurrent systems. Verification can be performed using efficient algorithms. This technique was born in the early '80s with the development by Clarke and Emerson (1981) of the first algorithm for verifying CTL (computation-tree logic) properties in finite-state models. Since then, model checking has been an active area of research and much more powerful algorithms have been developed, like symbolic model checking or bounded model checking, combined with simplification techniques like abstraction. Nowadays, they can be applied to process models with a very large number of states (Clarke et al., 1999). Another advantage of this technique is the rich expressiveness of the temporal logics, like LTL (linear-time logic) or CTL, used to define the verification properties. There are several widely used open-source model checkers, like Spin, SMV (Symbolic Model Verifier), or NuSMV, which provide implementations of the most important state-of-the-art model-checking algorithms.

Business processes are modeled using specific languages and formalisms. Each BPM system normally defines its own proprietary language. Although there are several initiatives that try to establish a common language like XPDL (XML [extensible markup language] process definition language), BPML (business process modeling language), or BPEL4WS (business process execution language for Web services), none of them have succeeded until now. Deductive verification and model checking are based on low-level state- or transition-based formalisms, like, for example, petri nets or finite-state machines. Therefore, state- or transition-based formal semantics should be added to process models in order to be analyzable with these techniques. When using queuing theory for performance analysis, transformation algorithms should be defined in order to obtain queue net models from process models.

Several research works have demonstrated the feasibility of formal methods for verifying business processes. In the following, we describe briefly some of the approaches that apply formal methods to BPA.

Aalst (1998) was a pioneer in this area. He proposed petri nets as a formalism for modeling business processes. He states that petri nets can model complex business processes, and that the powerful analysis techniques developed for them can be used to prove the correctness of business processes. These analysis techniques can be applied both for functional verification and performance measuring. On the one hand, they can be used to prove functional properties (safety properties like invariants, or liveness properties like the absence of deadlocks). On the other hand, they can be used to calculate performance measures like response times, waiting times, occupation rates, and so forth. Woflan (Aalst, 1999) is a tool that demonstrates the feasibility of this approach.

Eshuis and Wieringa (2002) realized that, although UML (Unified Modeling Language) activity diagrams were gaining popularity as a business-process modeling language, they were not suitable for performing analysis on them because of their lack of formal semantics. They designed specific semantics for modeling business processes using UML activity diagrams. Verification was performed by automatically transforming UML activity diagrams into verifiable SMV models.

In Wang et al. (2000), the authors use VerySoft and the model checker Spin to verify processes in e-commerce applications. The main problem of this solution is that it cannot be automated because it requires the modeler to code the verification models.

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