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Workflow simulation for operational decision support using event graph through process mining

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ABSTRACT

It is increasingly common to see computer-based simulation being used as a vehicle to model and analyze business processes in relation to process management and improvement. While there are a number of business process management (BPM) and business process simulation (BPS) methodologies, approaches and tools available, it is more desirable to have a systemic BPS approach for operational decision support, from constructing process models based on historical data to simulating processes for typical and common problems. In this paper, we have proposed a generic approach of BPS for operational decision support which includes business processes modeling and workflow simulation with the models generated. Processes are modeled with event graphs through process mining from workflow logs that have integrated comprehensive information about the control-flow, data and resource aspects of a business process. A case study of a credit card application is presented to illustrate the steps involved in constructing an event graph. The evaluation detail is also given in terms of precision, generalization and robustness. Based on the event graph model constructed, we simulate the process under different scenarios and analyze the simulation logs for three generic problems in the case study: 1) suitable resource allocation plan for different case arrival rates; 2) teamwork performance under different case arrival rates; and 3) evaluation and prediction for personal performances. Our experimental results show that the proposed approach is able to model business processes using event graphs and simulate the processes for common operational decision support which collectively play an important role in process management and improvement.

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1. Introduction

Business process management (BPM) has been attracting attention for more than a decade now, and its attention is now shifting from the enactment of business processes towards improving business processes [14]. The field of BPM now supports the design, enactment, control and analysis of business processes [41]. An important part of the evaluation of designed and redesigned business processes is business process simulation (BPS). It enables the analysis of business process models with respect to some performance characteristics such as throughput time, cost or resource utilization. In business process analysis and management, it is possible to have multiple change possibilities concerning the process. Therefore, design and redesign of business process play an important role in process performance improvement. Simulation is mentioned as one of the techniques suitable for the support of redesign [18]. After the simulation of a redesigned process, the simulation result is analyzed to provide a quantitative estimate of the impact that the redesign is likely to have on the process performance. The redesigned processes are compared with the current process helping us to make decisions on the best design.

There are a number of BPM and BPS methodologies, approaches and tools available for different applications. However, different model formalisms have different limitations, which make the simulation results deviate from real-world processes. Petri net is a prevailing formalism for process models. However, it is a non-trivial task to mine the relations between activities, such as choice and parallelism, in Petri net. Some tools can deal with loops, but each of them imposes restrictions on the structure of these loops. Although workflow logs contain rich information, e.g. timestamps, organizer and other process related data, they have not been made full use in the majority of existing modeling formalisms. Therefore, it is necessary to research a better formalism which integrates all the aspects of processes in the model so as to express processes more comprehensively. In the meantime, a generic and systemic approach of BPS is lacking for operational decision support, from constructing process models based on historical data to simulating processes for typical and common problems. Enterprises are increasingly using modern software tools such

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as workflow management systems and enterprise resource planning systems in BPM. As a result, these systems contain rich knowledge of business process in the form as historical data, which can be used to discover underlying process models. Based on these models, BPS can be carried out to estimate the impact on process and support operational decision-making when different design possibilities are considered to be implemented. Current research about BPS is primarily concerned with developing simulation theories, methods and software tools that will directly address the problem of process-based organizational design, but it lacks a generic BPS approach for decision support in general applications.

In our attempt to tackle these problems, we propose an approach of workflow simulation for operational decision support using event graphs, which are constructed from log files through process mining [22,43] to model business processes and is able to integrate various kinds of process-related information with their different elements. In BPM, we usually need to focus on these problems, i.e. finding a suitable resource allocation plan to help enterprises to economize on resources and reduce cost, judging whether the coming case arrival rate is under control with a specific resource allocation plan to adjust resources flexibly, and analyzing and evaluating personal performances. As a result, we simulate the process based on the generated event graph model under different scenarios and analyze the simulation logs for these three problems: 1) suitable resource allocation plan for a specific case arrival rate; 2) teamwork performance under different case arrival rates with a specific resource allocation plan; and 3) evaluation and prediction from personal performances. All these three problems play an important role in supporting operational decisions to optimize the process.

The rest of this paper is organized as follows. Section 2 reviews related work on BPS, event graph and process mining. Our approach for workflow simulation with event graphs through process mining is briefly outlined in Section 3. Section 4 elaborates the approach of deriving an event graph through process mining and its evaluation plans with a case study of a credit card application. The workflow simulation for operational decision support based on the generated event graph model is presented in Section 5. We discuss its comparison with Petri nets and our further considerations about event graph in Section 6. Section 7 concludes.

2. Related work

2.1. Business process simulation

2.1.1. State of the art of BPS

The idea of BPS is not new and there are many tutorials, reviews and surveys on it. Paul et al. [26] reviewed the current status of the BPM and BPS domains, discussed some pertinent issues for their successful deployment, and suggested a number of research directions for organizational modeling. Barber et al. [3] reviewed the diverse literature on different BPM and BPS methodologies, approaches and tools available in relation to manufacturing management. Evidence from the literature indicated that few tools are available for supporting manufacturing business process management and that, except for a few small-scale processes, BPS implementations in manufacturing have had limited success. They identified the reasons for this and suggested a practical way forward until hardware and software limitations were overcome. Melão and Pidd [23] surveyed the usage of simulation in the design, modification and improvement of business processes. Hlupic and Vreede [10] investigated the potential of simulation to be used for business process modeling for evaluating alternative business process arrangements, future trends and challenges in BPS. They also discussed business process modeling methods and tools and main challenges and opportunities.

2.1.2. Applications of BPS

In modern enterprises, business processes are increasingly recognized as the key to competitive survival. Hence, BPS is used as an important and effective tool to improve the performance of processes. There have been many successful applications reported on different topics, i.e. process management, process improvement and change management.

Aguilar et al. [2] presented to show how simulation was used successfully to support the building of process centered management in a banking environment. Tan [39] proposed an approach of BPS to predict the potential business impacts of introducing an information system. Liu et al. [20] proposed Petri nets extended with time and color as a formalism for supply chain event management.

In process improvement, Simon et al. [38] gave an example to discuss the use of Value Stream Analysis (VSA) to identify inefficiencies in business processes, how simulation was used to evaluate improvement plans/develop future business scenarios derived from this, and how simulation was used to match available resources to workloads. Jain and Ervin [13] described an effort utilizing modeling and simulation for evaluating the improvements in business processes and systems including a move towards e-business for a logistics and distribution supply chain.

Finally, for change management, Aguilar et al. [2] indicated how BPS could provide support in a process centered management approach to change. Greasley [8] presented a case study of the use of business process simulation within the context of a business-process-reengineering approach to change. Greasley [9] used BPS to evaluate the effect of the redesign of a police road traffic accident reporting system. The simulation method was demonstrated in the context of assisting process change enabled by the use of information systems in an organization in which there had been a historically mixed pattern of success in this activity. Zhang et al. [51] proposed an approach of simulating processes for runtime change management with event graphs.

2.1.3. Modeling formalisms for BPS

Due to different process modeling formalisms, the theoretical basis and implementation solution of BPS are also different from each other. We observe that there are three main formalisms, i.e. Petri net, IDEF and UML.

In process mining and modeling, Petri net is a prevailing formalism so there has been a lot of research about business process modeling and simulation with it. For example, Jörg and Thomas [16] simulated business processes with Petri net models by generating partially ordered runs and they also showed how these runs could then be used for performance analysis of important key indicators such as throughput time. With workflow technology, Petri net theory and simulation technology, a workflow engine independent business process analyzing system was realized to provide Petri net-based business process analysis [45]. Great work on BPS based on Petri net has been done by the Architecture of Information Systems (AIS) group. Reijers and ver dan Aalst [27] introduced short-term simulation by showing the relations and differences between strategic simulation and operational control. The data that might be used for this kind of decision was outlined and a simulation architecture applied in practice was also presented. Although simulation was used to analyze business processes at some stage, it was not used in a structured and effective manner. ver dan Aalst et al. [44] argued that there were also several additional and more fundamental problems. For example, the focus was mainly on design, not for operational decision-making. There was limited support for using existing artifacts such as historical data and workflow schemas. The behavior of resources was modeled in a rather naive manner. Focusing on the latter problem, it proposed a new way of characterizing resource availability. Experiments using CPN Tools showed that it was indeed possible to capture human behavior in business processes in a better way. Wynn et al. [30,48]

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