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Prediction of business process durations using non-Markovian stochastic Petri nets

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ABSTRACT

Companies need to efficiently manage their business processes to deliver products and services in time. Therefore, they monitor the progress of individual cases to be able to timely detect undesired deviations and to react accordingly. For example, companies can decide to speed up process execution by raising alerts or by using additional resources, which increases the chance that a certain deadline or service level agreement can be met. Central to such process control is accurate prediction of the remaining time of a case and the estimation of the risk of missing a deadline.

To achieve this goal, we use a specific kind of stochastic Petri nets that can capture arbitrary duration distributions. Thereby, we are able to achieve higher prediction accuracy than related approaches. Further, we evaluate the approach in comparison to state of the art approaches and show the potential of exploiting a so far untapped source of information: the *elapsed time* since the last observed event. Real-world case studies in the financial and logistics domain serve to illustrate and evaluate the approach presented.

1. Introduction

Managing a company's business processes is critical for its success in a competitive market environment [1,2]. Not only is it important to strategically align the business processes with the company's goals, the daily operational support of business processes is also necessary to ensure smooth operation [3].

Psychological studies show that waiting time has a negative impact on customer satisfaction [4]. While companies cannot completely avoid waiting times for economic considerations, they can and should use all available information to provide their customers with reliable estimates of remaining time. An approach is to offer waiting time guarantees to customers. Kumar et al. show that these guarantees improve customer satisfaction, if they are met [5]. Such waiting time guarantees are common in various domains (e.g., fast food, travel, finance), where customers get compensated if their waiting time exceeds the agreed thresholds.

The increasing degree of automation by process oriented information systems and the adoption of sensing devices in business processes [6] produce large amounts of process execution data. These data hold valuable information which can be used for analyses in the context of business process intelligence. This paper focuses on the temporal performance aspect of business processes. In fact, we use expressive probabilistic models that we enrich with information extracted from event data [7]. Most prominently, performance models are used to predict remaining durations [8–10] and to estimate the risk of missing a given deadline [11,12]

Based on these insights, we offer means to accurately predict remaining durations, and to compute risks to

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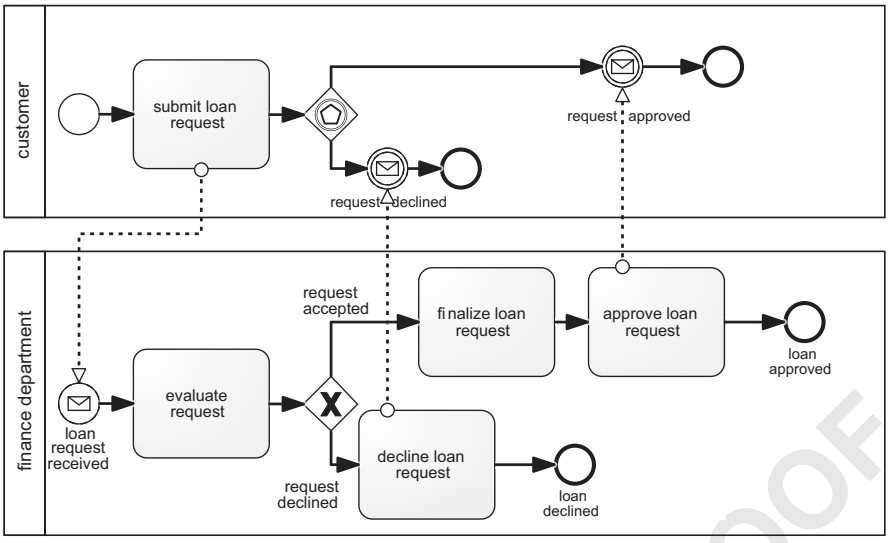

Fig. 1. Loan application process as BPMN model. After a client requests a loan by submitting a request to the finance department, it is first evaluated. Depending on the evaluation, the loan can either be declined, or accepted. If accepted, the loan request will be finalized and an approved. The client is notified in any case about the decision.

breach temporal deadlines or guarantees. Thereby, we exploit the information of elapsed time since the last event to increase accuracy. These means can be also used to compute reasonable waiting time guarantees, e.g., the waiting time that is met in 99 percent of the cases. Moreover, the approach presented in this paper can be applied in resource management, where an accurate predictor and knowledge about the uncertainty for remaining time of activities is critical for effective scheduling [13].

Summarizing the contributions of this paper, we rely on an expressive stochastic performance model of a business process to:

- predict the expected remaining duration of a business process,
- predict the risk of breaching a temporal deadline,
- use elapsed time as a means to improve prediction accuracy,
- evaluate the model against state of the art approaches.

The remainder of the paper is structured as follows. In Section 2, we formally introduce the concepts and the model used in the prediction approach with a motivating example. Next, in Section 3, we present the approach to predict remaining time including associated confidence intervals, and also predict risk of breaching a temporal boundary. We overview related approaches in Section 4 and highlight differences to and synergies with our approach. Subsequently, Section 5 provides an evaluation with the state of the art and discusses the results. We conclude the paper in Section 6 with reflections on limitations and next steps.

2. Preliminaries and motivating example

To best illustrate the approach for prediction, we introduce a running example from the finance domain. Fig. 1 depicts a loan approval process as a BPMN [14] diagram. In this process, there are two communicating partners: the client and the financial department of a bank. The client can start a loan process by submitting a loan request to the financial department. After that, the client waits for a reply. Meanwhile, the request is evaluated in the financial department and, depending on the evaluation, the loan is either accepted or declined. If declined, the client is notified and the process terminates. If the loan request is accepted, it must be first finalized and then can be approved by sending a notification.

In this process, the financial department has implemented a service level agreement (SLA) that states that the response will be sent to the client latest after 5 business days. In case of a later response the client is offered a compensation. Also, the management would like to have an estimate of the remaining case durations without having to ask the process participants to avoid excess communication. The vision is to also make the remaining duration estimates available to the affected clients of the bank, to further increase customer satisfaction. In this context, we investigate two issues: predicting the remaining duration and estimating the risk of deadline transgression in business processes.

Next, we define event logs that reflect the data gathered from information systems or sensors in a process execution environment. Let A be a set of process activities and $\mathbb{TD}$ be the time domain.

Definition 1 (*Event log*). An event log over a set of activities A and time domain $\mathbb{TD}$ is defined as $L_{A,\mathbb{TD}} = (E, I, \alpha, \gamma, \vartheta)$, where

- E is a finite set of events
- I is a finite set of cases (process instances),
- $\alpha: E \to A$ is a function assigning each event to an activity.
- $\gamma: E \to I$ is a surjective function assigning each event to

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