Change Recommendation in Business Processes

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Abstract. Process-aware information systems are valuable for automating business tasks leading to cost reduction and efficiency. This research aims to advance the state of the art in process management towards autonomic process performance improvement by contributing control-flow change recommendations for process instances that is supporting automatic change enactment as a response to predicted KPI violations. Towards that goal, the related literature has been investigated in two literature review studies and research gaps have been identified. The proposed generic architecture provides a feedback loop that enables evaluation of the resulting recommendations for future process instances. We also present the current state of the research and future plans.

Keywords: Autonomic process performance improvement · Recommender systems · Process monitoring · Process change/adaptation · Key Performance Indicators (KPIs) · Process-aware information systems · (Business) process management

1 Introduction

Business process management research focuses on all phases of process life cycle and process-aware information systems (PAIS) have been developed to enable all available concepts and techniques in these phases. The most recent advances in predictive monitoring of processes [1, 4, 5] enable a number of performance indicator predictions, such as process instance remaining time, cost, or process instance outcome. Currently, such estimations are used by business owners and other stakeholders to recommend process improvements, however, we observe that there is still a disconnect between the tools for predictive monitoring and the process execution environments, which makes the automated recommendation and enactment of changes for running process cases/instances impossible. This in turn prohibits the advancement toward autonomic process performance improvement [6] and is the main objective of our research.

The initial benefit of using process-aware information systems for business processes is to allow for monitoring key performance indicators (KPIs) to different stakeholders (via e.g. a dashboard) to provide a general overview of the current state of running process instances and thus support decision making. In addition, current developments in research allow for logs to be used for further

assistance in decision-making by predictions and recommending actions based on them. Therefore, the long-term research objective is to contribute to this assistance by recommending changes in business processes based on the learned impact of changes/adaptations on process KPIs. In this research specifically, our goal is to focus on KPI violation prevention by recommending process control-flow changes using a learned model on historical data.

The general idea is to utilize advances of the artificial intelligence research and extend the flexibility of processes in run time using the prediction capabilities of the literature in the predictive monitoring area to take change actions. This idea has been identified in our previous study [6]. In addition, [2] proposes a research manifesto on augmented business process management systems, where artificial intelligence techniques aid in making processes in a PAIS more adaptable, proactive, explainable, and context-sensitive.

Towards that goal, we performed 2 literature review studies considering the guidelines for conducting a systematic literature review [3] and identified the limitations of the current research. In an attempt to address some of these limitations, we will focus on providing a recommender system for change recommendation and how it will be integrated into PAIS. We will work towards this contribution along the following three steps: i) synthetic event log generation, ii) correlation identification between process log attributes, need for change and type of change action/pattern, and iii) control-flow change recommendation.

We will present the approach, preliminary results and future steps as follows: Section 2 investigates the related work by representing our reviews of literature. Section 3 illustrates a big picture of the approach and our research road map. Current research on the change recommendation and preliminary results have been explained in section 4. In the end, section 5 concludes the paper.

2 Related Work

We have carried out two literature reviews to capture the current state of the art.

Our *Literature review on prediction and change of business processes* looked into the available works that report concepts and solutions to combine "prediction" and "change" on a process, service composition, or service choreography [6].

The studies we identified in this review[1] apply various change approaches such as control-flow change, service replacement, service/fragment substitution, and data manipulation. The type of systems considered is service composition in most of the studies and service choreography in only one study. Although some studies facilitate KPI prediction, the prediction approaches considered in the literature do not thoroughly study the three main dimensions of KPIs – time, cost, and quality. Furthermore, we concluded that there are no process-aware solutions available that enable the combination of process adaptation and predictive process monitoring natively in generic manner and automatically, so

[1] https://docs.google.com/spreadsheets/d/1Vb56k0xxGHvqPaEdbdONVg7lqaRICDf5

that they can enable an autonomic feedback loop. The research limitations are in terms of reference architectures and in term of detailed concepts and realizations relevant to the autonomic PAIS.

In our *literature review on learning from the changes in business processes*, we consider works that focus on recording or mining of changes in a business process, workflow, service composition, service orchestration, or PAIS in general.

Among the identified studies that consider learning from changes[2] , only one study mentions change recommendation in a proposed framework. The proposed approach, however, is different from our approach as it considers process variants, whereas, we are interested in the changes for KPI improvements. Overall the sparse literature shows that this area has the potential to be further explored and is relevant to the findings in our literature review on autonomic process change based on predictions.

3 Approach Overview and Research Road Map

Aligned with the general goal of autonomic process performance improvement, we proposed a generic architecture shown in Fig. 1 in a previous study [6], where we reconstructed the architecture based on existing realizations identified in our first literature review. This architecture shows 5 logical component groups shown in dotted lines. On the left side of the architecture, there is a process execution environment (PAIS). This system sends monitoring data to the monitoring component that stores process execution data as logs. These logs will then be used by the analysis component for further analysis and by the prediction component. The prediction component is where the works on predictive monitoring of business processes could be applied. In addition, this component consumes processed data from the analysis component. As a result of predictions on process instances, violations may arise and then could indicate a trigger for change. The adaptation component handles changes on process instances and feeds back the need for change enactment into the PAIS, thus closing the feedback loop. On the basis of this architecture, the ultimate goal of this research is to enable control-flow change recommendations based on the predictions produced by the prediction component. The proposed recommender system extends the part of the architecture dealing with adaptation identification and enactment. Significant part of the approach is related to measuring and recording the impact of the recommended changes onto processes and learning from that information for continuous learning of the adaptations.

Following the presented generic architecture in [6], we proposed a research road map. In this road map, a research direction has been noted to identify the best type of change upon detection of a certain type of violation and the way this change is selected and its effects will be measured. Following this research road map, the research on the control-flow change recommendation has been investigated. In the scope of this research, the research challenges/questions for the control-flow change recommendation we identified are:

[2] https://docs.google.com/spreadsheets/d/1VZ1R43SakuVCG25ZqXcIiFzyIkaF7W2i

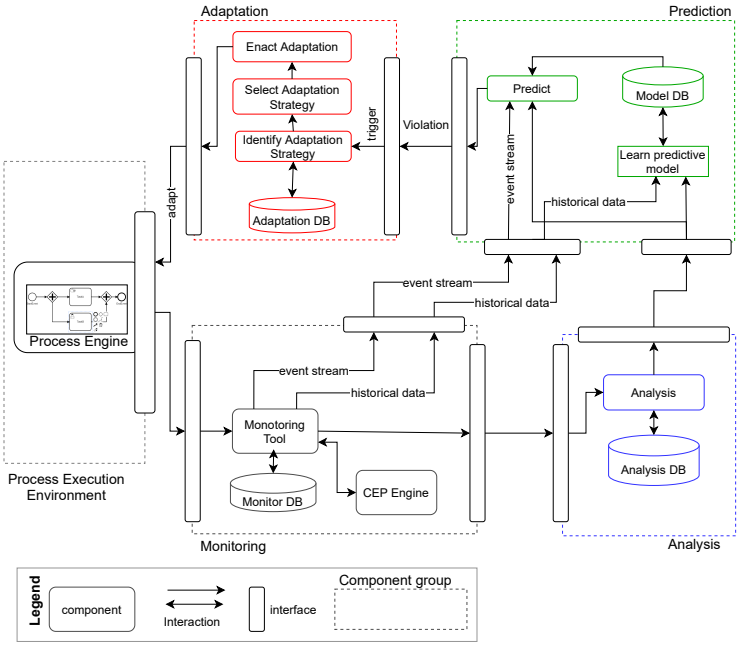

Fig. 1. Generic architecture of a system enabling autonomic process performance improvement [6]

- How can we learn from the process instances that exhibit control-flow changes?
- How can we map what is learned from the process instances to control-flow changes?
- How a learned model from the process instances with control-flow changes could be used for change recommendation?

In the next section we will present the preliminary results towards addressing these open research questions.

4 Change Recommendation - Preliminary Results

As mentioned above, overall, two literature review studies have been conducted to identify available literature and gaps in the research area. Following the identified gaps, a generic architecture for autonomic process performance improvement has been proposed. To complete the autonomic loop and make the manual part of changing the processes assisted, a control-flow change recommendation research direction is currently being investigated.

Control-flow change recommendation follows the research road map presented in [6] and contributes to the automation of the adaptation component demonstrated in Fig. 1. This research objective has been broken into 3 steps explained below.

Step 1: Synthetic event log generation. The objective of this step is to generate synthetic event logs that contain process cases with control-flow changes. The challenge of this work is to generate synthetic event logs that resemble the real event logs of businesses. To address this challenge, we inject change patterns in the data assuming that there are discoverable patterns in real data. In addition, noise is added to data as another factor. A sample of a generated synthetic event log is available[3].

The reason for this step is twofold, first, there are no publicly available real life event logs comprising changes carried out on running instances with the purpose of improving their KPIs proactively. Second, this step will give us more control over the experiments and will help future research in the field to use business process simulation for purpose-specific event log generation.

In the end, the generated event logs will be verified. In the verification stage, the number of process traces, number of events and average process instance duration will be reported.

Step 2: Correlation identification in the event logs. This step aims to identify the correlations between process log attributes, need for change (with focus on the time KPI) and type of change action/pattern and show them in a model in order to be used for categorizing process cases and label them for the change action/pattern. The challenge of this step is to identify a method that can extract these correlations and show them in an interpretable model. To address this challenge, decision tree machine learning methods have been chosen due to their interpretablity. A sample of the resulting decision tree trained on the encoded event logs is demonstrated in Listing 1.

```
1 trace_duration <= 249.81615: False (587.0)
2 trace_duration > 249.81615: True (413.0)
```

Listing 1: Learned decision tree on synthetic event logs for a sample process model

The model in Listing 1 explains that the traces with a total duration above 249.8 minutes are considered to be the cases with a control-flow change (i.e. the change label is True for these cases) and without change otherwise. Note that this model is very simplistic as the generated synthetic data was used to examine the learning ability of the decision tree learning method. An experiment on real data would demonstrate a more realistic model.

To evaluate the learned model, machine learning metrics (such as F-measure) will be considered. To prevent over-fitting, experiments consider cross-validation of the data. In addition, a comparative experiment on the different supervised machine learning methods will be beneficial to compare the effectiveness.

[3] https://docs.google.com/spreadsheets/d/1gifw6Zt9Ie_vSxbiHZlW57d2iw_nd3-b2iQnqp0BSmw

Step 3: Control-flow change recommendation. This is the final step towards the goal of recommending control-flow changes for process cases, which consumes the learned model in the previous step. In this step, the data of a process case in the event logs will be labeled for the type of control-flow change required based on the learned model (specifically, a decision tree similar to the sample shown in Listing 1). This label will give a recommendation for control-flow change.

The control-flow change recommender will be evaluated by comparing the recommended change and the change label of the process cases in the synthetic event logs. If the real label and the recommended change are equal, it is considered a successful recommendation and an unsuccessful recommendation otherwise.

Overall, we plan to design a simple basic experiment for each step and move towards more complicated experiments with multiple control-flow change possibilities and consider more aspects of a real-world setting.

5 Conclusion

This paper aims towards autonomic process performance improvement by referring to the identified gaps in the state of the art, which are captured in literature review studies. A control-flow change recommendation on business process cases is under study, which has been explained in this paper using a three steps approach of synthetic event log generation, correlation identification in the event logs, and control-flow change recommendation. In future, we plan to continue the research on process change recommendation considering the generic architecture and the research road map. This research will provide insights for academia on purpose-oriented process data generation and contribute in applying machine learning methods in process-aware information systems. It will also benefit industry by providing change recommendations in processes and assisting in KPI-oriented decision making.

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