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Paper title: Machine Learning in Business Process Monitoring: A Comparison of Deep Learning and Classical Approaches Used for Outcome Prediction

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Keywords specific to the paper: predictive process monitoring; business process management; outcome prediction; deep learning; machine learning

Summary of the main contributions:

For the past decades, using big data-driven approaches in business processes like the monitoring phase have been gaining companies' attention. Being in a fast-changing market, gaining predictive insights where data is used in real-time to forecast process behavior, performance, and outcomes helps organizations act rapidly and efficiently. The paper discusses the application of machine learning (ML) and deep learning (DL) techniques for predictive monitoring of business processes. The study aims to identify log properties that facilitate the use of DL techniques through AI models for outcome-oriented predictive process monitoring. Hence, the event log properties that facilitate the use of DL techniques for outcome-oriented predictive process monitoring are identified by first compiling five event logs: BPI Challenge 2011, the first event log in healthcare process whereas each event log refers to the cancer treatment of one patient. The second event log used is BPI Challenge 2013, that shows an incident management process in which a mechanism needs to be monitored. The third event log is Road Traffic Fine Management Process (RTFMP log) that contains a process for handling traffic regulation infringements. The fourth event log comes from a company resource planning system in a production process, which is called production log (PL). The last event log is the review log (RL), where one editor must accept or reject an activity based on recommendations of multiple reviewers.

The paper accentuates the comparison of the performance between ML and DL techniques using these multiple event logs and performance evaluation metrics. An event log is a part of the operating system, which stores the event log as a file during the monitoring cycle. As for evaluation metrics, there are four principal ones but two were the most used in the study. The most common one is accuracy, which represents the numbers of correct predictions. Then, the precision metric is used to prove that the assessed numbers of predictions are problematic as expected. The paper mentions that, with the event log properties being identified and assessed with the techniques used through AI models, we can effectively learn from stored data to predict future outcomes and facilitate outcome-oriented predictive process monitoring. These event logs provide results showing which technique assessed and studied was the best. However, the article also highlights the necessity to do more research and analysis on DL techniques to increase business surplus value in companies and efficient process management. As a matter of fact, DL is still very new in terms of application compared to ML when it comes to business processes. Companies should invest in applying AI-based DL models, unless in certain situations where DL only slightly outperforms them. In summary, the study suggests that DL techniques are relatively more interesting for outcome-oriented predictive process monitoring while classical ML techniques may still be relevant depending on the field of implementation.

AI model used:

- **Introducing the AI models**

The comparison of machine learning (ML) and deep learning (DL) techniques shows that predictive process monitoring belongs to supervised machine learning models. The AI models used in the article include Random Forests (RF), Support Vector Machines (SVM),

and shallow neural networks, which are part of ML. RF is the first AI model that builds multiple decision trees during training and combines their predictions to make more accurate data classifications or predictions. As for SVM, it is also used to detect problems by performing data classification. RF and SVM are part of the ML techniques here. Nevertheless, the study also talks about AI models such as Long Short-Term Memory networks (LSTM) and deep neural networks (DNN), as representatives of DL. LSTM is used to process and predict data for some time while assessing encountered problems with classic DL AI model like RNN (recurrent neural network that now possesses limitations). As for DNN, it is more complex than all the others above because it is better when it comes to data extraction and monitoring at different levels, since it is closer to human-like behavior. The comparison of these AI models is based on their performance in predictive process monitoring using five event logs, with the goal of identifying the log properties that facilitate the use of DL techniques. The article demonstrates that DL outperforms classical ML approaches. The results show that AI models such as LSTM and DNN generally showed better performance compared to classical ML techniques, like RF and SVM across important evaluation metrics such as accuracy and precision.

- **How do they contribute the idea proposed by the paper?**

ML and DL techniques were used for outcome-oriented predictive process monitoring using various evaluation metrics. To further study the results, the researchers similarly encoded every log for each prediction at the same time point to show the real difference between them. This study aims to identify the greatest performers out of all the AI models cited. The AI models evaluated include RF, SVM, DNN and LSTM. Based on the evaluation metrics, the DL techniques, particularly DNN and LSTM, generally outperform the classical ML techniques (RF and SVM) across various prediction time points. Specifically, DNN and LSTM show higher accuracy and precision metric values compared to RF and SVM. Additionally, DL techniques have more stability and precision for earlier prediction time points and the others show latency. Furthermore, LSTM outperforms DNN regarding accuracy for some specific logs observed in the event logs.
In summary, the DL models, especially LSTM, demonstrate greater performance in terms of accuracy and temporal stability compared to the classical ML models. It is mentioned that increasing availability of data lowers the barriers of using ML. But although the popularity of DL has increased in predictive process monitoring, most still use classical ML techniques. Either way, the models help by monitoring early predictions. It is always beneficial in terms of savings related to cost, time, and corporate resources in business process management. Therefore, based on the article's results, DL techniques are generally considered to be more effective for outcome-oriented predictive process monitoring compared to classical ML approaches. However, the decision to use DL or ML techniques should also be considered by companies when it comes to organizational and economic factors, as well as the specific log properties and prediction tasks involved.

Supported by a software application? (If yes, provide more details)

To build LSTM and DNN classifiers, they implemented a learning scheme using Python, in which they optimized hyper-parameters. Python is a programming language used as a foundation for the application of AI models. To explain further, in Python a hyperparameter is a parameter whose value is set before the learning process begins. These parameters cannot be learned directly from the data, but they need to be specified to the model before the training to get good and highly efficient predictive outcome results.

For RF and SVM classifiers, they used Scikit-Learn from Python as well. Scikit-Learn is a library that provides tools for model evaluation and selection, such as cross-validation, hyperparameter tuning, and performance metrics.