INTEGRATING PROCESS MINING, ROBOTIC PROCESS AUTOMATION, AND DATA MINING: A FRAMEWORK FOR OPTIMIZING INVENTORY MANAGEMENT

Farah Altarazi, Industrial and Systems Engineering, Ph.D. Candidate

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ABSTRACT

Process mining, Robotic Process Automation (RPA), and data mining are increasingly leveraged in digital transformation initiatives to enhance and optimize company processes while supporting informed, data-driven decision-making. However, their combined integration remains insufficiently explored. This study establishes two primary objectives to address this gap: (1) to develop a robust framework that integrates process mining, RPA, and data mining techniques—covering the entire lifecycle from process selection to post-implementation evaluation; and (2) to apply the developed framework to a real-world case focused on inventory management challenges. This involves identifying and automating suitable processes, evaluating RPA effectiveness, and utilizing data mining insights to enhance inventory management practices.

A systematic literature review has been conducted by reviewing forty-seven papers that include the integration of at least two of the technologies considered. The aim of this review is to discover how process mining, RPA, and data mining have been implemented in combination across different industries, including the integration impact, challenges, and to identify gaps in the integration of these technologies. It also provides recommendations for future studies. The review results in several conclusions, one of the key findings being a gap in the availability of studies or frameworks that combine all three technologies. A comprehensive review of some of the papers considered, which included integration frameworks for at least two of the technologies, was used as a foundation for establishing the proposed framework that integrates all three technologies while addressing existing gaps in their integration.

The proposed framework consists of five main stages: first, manual processing to collect process data using process mining to better understand the current situation and identify suitable processes for automation; then applying RPA and evaluating the integration using conformance checking techniques; and integrating data mining techniques in between to use the data generated from inventory reporting to enhance the inventory management process. The data mining techniques are evaluated to determine the best fit model for the considered data.

The framework was applied to a real-world case to help solve inventory management challenges faced by an electronic packaging company. The challenges involved two key issues: complexity in the current process of updating inventory reports and the complex data structure of current inventory management reports. The results of applying the framework show a significant impact on both process enhancement and inventory predictions. For example, the throughput time to conduct one of the considered cases in managing inventory improved by 73.70%. Also, the manual process achieved a fitness score of 0.83, while the RPA implementation reached a perfect score of 1, demonstrating that the automated process aligned flawlessly with the model. For inventory predictions, the suggested models, ARIMAX and machine learning models (including Random Forest, Gradient Boosting, K-Nearest Neighbors, and Decision Tree) were used for forecasting inventory levels. Clustering was applied to inventory items, which enhanced the process and yielded improved results. Among all models, Random Forest proved to be the most reliable, capturing non-linear relationships and interactions in the data, and achieving superior forecasting accuracy. The combination of clustering and machine learning enhanced the model's ability to adapt to complex inventory behavior, leading to more precise and targeted forecasts.

These results demonstrate the framework's ability to transform manual inventory processes into efficient, automated workflows, supported by data-driven insights. The combination of process mining, RPA, and data mining addressed operational inefficiencies, improved predictive accuracy, and offered a scalable solution for inventory management challenges. For future work, several avenues can enhance the framework and its applications. Integrating stochastic models could address uncertainty in inventory management, improving adaptability in environments with fluctuating demand and supply. Applying the framework across industries like healthcare and manufacturing would help evaluate its scalability and adaptability, uncovering new insights. Additionally, exploring advanced machine learning techniques, such as deep learning or reinforcement learning, could enhance predictive capabilities and improve automation and forecasting accuracy. Finally, investigating the incorporation of a human-in-the-loop decision-making process could enhance flexibility and allow for more effective handling of exceptional cases or uncertainties.