An End-To-End Execution of a Logistic Process in an AI-Augmented Business Process Management System

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Abstract

This paper presents an end-to-end execution of a real-world business process (BP) in the logistics domain to illustrate how an AI-Augmented Business Process Management System (ABPMS) can increase BP automation compared to a traditional BPMS. In addition, we discuss concrete AI-based solutions for the implementation of the ABPMS lifecycle stages.

Keywords

AI-augmented Business Process Management System (ABPMS), Process Framing, Sense-Think-Act Cycle, AI Planning, Knowledge Representation and Reasoning, Robotic Process Automation, Conversational AI

1. Introduction

AI-augmented Business Process Management Systems (ABPMSs) [1] are an emerging class of process-aware information systems infused with AI that autonomously unfold and adapt the execution flow of business processes (BPs) through continuous conversation with their human principals. The lifecycle of an ABPMS extends that of a conventional BPMS in two directions:

- The traditional lifecycle stages of a BPMS (i.e., *frame, perceive, reason, enact*) are augmented with AI. Process framing entails establishing multiple constraints encompassing procedural rules, best practices, and norms that must be considered during the execution of a BP [2]. Once an initial framing is completed, the lifecycle enters its central stage, namely *process-aware execution*. This consists of the rotation between perceiving, reasoning, and enactment. First, the ABPMS *perceives* data concerning the BP execution and produced by the working environment (e.g., collected through IoT sensors). Following data perception, the system engages in *reasoning* activities, converting collected data into relevant events, pondering about their uncertainty, and combining them with the BP towards deciding which actions to take next. This pertains to a wide repertoire of AI techniques, such as data integration, knowledge graph construction, AI planning, etc. Finally, the ABPMS leverages its actuators to interact with the environment and *enact* the BP as long as the boundaries imposed by the frame are respected.

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- At any stage throughout the lifecycle, the ABPMS may perform one of the advanced stages (i.e., *explain, adapt, improve*) that are specific to ABPMSs and only feasible when AI is an integral part of the system. The ABPMS may decide to: provide *explanations* about the past, current, and anticipated states of the system; *adapt* itself to new circumstances and drifts; and *optimize* its execution against its goals, the available resources, and the framing constraints. The implementation of these advanced stages could lead the ABPMS to update its internal knowledge, consequently reframing itself in an autonomous manner. Note that the ABPMS can proactively communicate with its human principals (who may oversee the system decision) about BP-related actions, goals, and intentions.

The BPM literature is plenty of AI-based techniques that cover the life-cycle stages of an ABPMS in isolation. For example, in [2] the author positions in favor of constraint-based declarative BP specifications for process framing without delving into the execution stages. Other studies focus on conversational systems as tools to enhance the execution stages of ABPMSs [3, 4], neglecting the flexible nature of process framing. In [5, 6], AI planning and reasoning-based approaches are employed to the automated adaptation of BPs in response to unanticipated exceptions. However, these adaptations are not explained nor used to reframe the original BP specification. The need for explainable solutions to increase trust in the interaction with the ABPMS is investigated in [7]. In [8], the authors present a methodology for BP optimization based on conformance checking and performance analysis via statistical inference.

However, the literature lacks a holistic description of how an ABPMS should execute a real-world BP encompassing all its life-cycle stages, thus concealing the advanced automated features of ABPMSs over traditional BPMSs. In this paper, we mitigate this gap by presenting the details of an end-to-end execution of a BP from the logistics domain performed through an ABPMS, showing how introducing AI technology into conventional BPM creates a range of opportunities to boost BP automation in all the ABPMS life-cycle stages.

2. Executing a Logistic Process with an ABPMS

In this section we illustrate with a real-world example drawn from the logistics domain and presented in [9], how an ABPMS can enhance the execution of a BP compared to a traditional BPMS not empowered by AI technology. Specifically, we use a running example of a BP for transporting perishable products whose safety and quality highly depend on controlling temperature and humidity from origin (harvest fields) to consumption, and we show how the stages provided by an ABPMS can enhance the execution of the BP. Fig. 1 presents the BP model in BPMN.[1] In our example, this constitutes the instantiation of the *frame* stage, which relies on the aforementioned BPMN model to guide and constrain the execution of the BP. While the frame for this specific BP is rigid, as we are adopting a prescriptive model, in an ABPMS the frame specification can be enriched through declarative constraints (e.g., based on Linear Temporal Logic over finite traces (LTLf) [10]) to be monitored at run-time. For example, the frame can include constraints to capture and react to events that break the BP boundaries (e.g., if a pallet lacks a label to identify it), deviating from what is expected.

[1]We refer here to the last release of BPMN, namely BPMN v2.0 – http://www.omg.org/spec/BPMN/2.0/

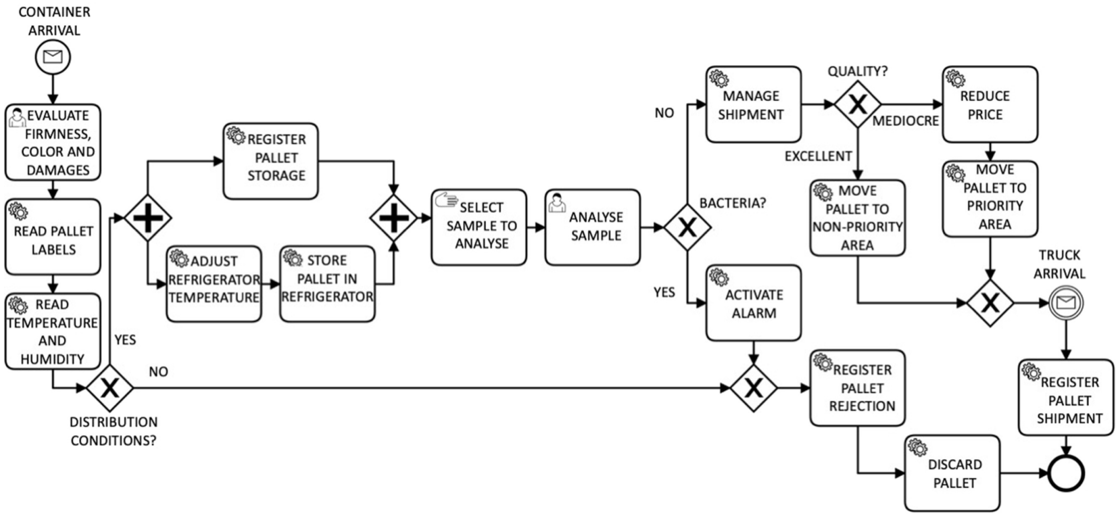

Figure 1: BPMN representation of a real-world BP from the logistics domain.

The process-aware execution (i.e., *perceive*, *reason*, and *enact*) of the ABPMS is triggered when the BP starts, that is, when a container with a pallet arrives at the smart distribution center. Here, a human operator verifies the quality of the products of the pallet. Subsequently, information about the received product (such as origin, harvest date, etc.) is automatically detected by reading the pallet labels (barcodes or QR codes). The temperature and humidity of the container are also automatically detected through dedicated sensors. Based on all this collected information, a decision is made regarding whether the products are of good quality or not. Moving forward from the initial phase, if the products are considered not for distribution, the rejection of the pallet is registered and it is discarded by moving it to a garbage. Conversely, if the products meet quality standards, the pallet is logged and sent to a climate-controlled chamber in the distribution center. This ensures proper storage conditions (e.g., oranges must be kept between 2 and 12 Celsius degrees and at 90% relative humidity). Continuing with the execution of the BP, besides this first product control, a second one is performed over a sample in the laboratory. This analysis will determine whether moulds, yeast, and certain bacteria have grown in the received products. When any of these contaminants is detected, an alarm triggers and the pallet is discarded by transporting it to the garbage. Conversely, the shipment task of the received products can start. At the end, if products quality is not excellent, such as being suitable for distribution but lacking optimal firmness or color, their prices are reduced and the pallet is prioritized to avoid their spoilage. Finally, once a truck is ready for transportation, all shipped pallets are registered in the system. This is essentially the sense-think-act cycle [11] that is implemented by the ABPMS within this scenario.

Indeed, guided by the view exposed in [1], an ABPMS could enhance its process-aware execution by augmenting the *perceive*, *reasoning* and *enact* stages with AI technologies. For example, AI techniques for data filtering [12] can indeed be utilized to augment the *perceive* stage, e.g., to process the sensed data of a pallet (origin, harvest date, temperature, humidity, etc.) and automatically rejecting those ones that do not meet quality standards. Meanwhile, AI techniques such as Situation Calculus [13] can bolster the *reasoning* stage, thereby assisting human operators in the decision-making phases of the BP, potentially even automating them [14]. For instance, when the pallet is sent to a climate-controlled chamber in the distribution center a Situation Calculus reasoner could be employed to reason on the actions to be taken to guarantee its optimal conservation by automatically regulating the temperature of the fridge. When considering the *enact* stage, for instance, when all shipped pallets must be recorded in the system, Robotic Process Automation (RPA) [15, 16] techniques could be leveraged. The registration procedure could be automated using traditional vendors of RPA tools (e.g., UiPath[2]).

The previous stages can be extended also with the advanced stages unique to ABPMSs, as explained as follows. The *explain* stage can be enacted whenever explanations regarding the system's states are needed within the BP execution. For instance, it can provide a detailed explanation of quality controls, why a product was evaluated as being in good condition or not, as well as why the product was rejected and the actions taken in response to the rejection. Lastly, through explanation, the ABPMS could provide transparent insights into the reasoning behind pricing decisions and shipment prioritization. To this end, eXplainable Artificial Intelligence (XAI), is a field of study focused on developing techniques to make decisions more transparent and understandable to humans. In the context of explaining decision logic to users, XAI methods could provide insights into why an ABPMS made a particular decision or prediction. Two popular techniques for this purpose are LIME [17] (Local Interpretable Model-agnostic Explanations) and SHAP (SHapley Additive exPlanations) [18] which can be customized ad-hoc.

The other stage implemented by the ABPMS is *adapt*, wherein the system modifies its operations in response to any unexpected change. This advanced stage could yield numerous benefits for the BP. For example, the ABPMS could dynamically adjust pricing strategies and shipment prioritization based on real-time factors such as demand fluctuations or perishability levels to optimize revenue and minimize waste. Also, if there is a sudden spike in laboratory contamination levels, the ABPMS could automatically trigger enhanced sanitation protocols or halt shipments until the issue is resolved. In this direction, Automated Planning techniques in AI [19] could be employed for the automated synthesis of these strategies, thus adapting the execution of the BP according to the many factors of interest.

Finally, the BP execution of the presented scenario can be further enhanced in the *improve* stage. By analyzing historical data, the system can identify recurring patterns of rejected products using patterns recognition techniques [12]. For example, if certain types of product damage have not been previously detected, the system can recommend the introduction of new evaluation criteria and updates to control procedures. Additionally, it may detect patterns indicating a supplier's tendency to deliver defective products or a specific product's susceptibility to damage, thus enabling self-improvement by suggesting additional checks for specific suppliers and/or products. Improvement efforts could also involve utilizing performance metrics to refine storage and preservation processes over time. Through the analysis of patterns in product spoilage or storage inefficiencies, the ABPMS could propose optimizations such as revised temperature control algorithms or enhanced packaging protocols to minimize waste and maximize product lifespan.

[2]https://www.uipath.com/

3. Concluding Remarks

In this paper we examined an end-to-end instantiation of a real-world logistic BP within the stages of an ABPMS. In particular, we emphasized the role of AI to boost BP automation in all the ABPMS life-cycle stages. Through this analysis, we not only offered a tangible end-to-end perspective on how ABPMSs execute and optimize BPs, but we also highlighted their potential to support the human workforce in performing related tasks.

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