Knowledge-intensive Process: A Research Framework

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Abstract. Great value is now being credited to the so-called Knowledge-intensive Processes (KiP) benefiting from the advent and proliferation of social media, smart devices, real-time computing, and technologies for big data. Our research investigates the origin, formalization, and support for KiP towards what we call a Knowledge-intensive Process-Aware Information System (KiPAIS). We propose a research framework to address the following challenges, aligned with the pillars of the CBPM due to intrinsic relationships among them: (1) eliciting and discovering KiP; (2) representation and support to the implementation of KiP; (3) formal theory capable of explaining KiP; (4) measuring the performance of KiP.

Keywords: Knowledge-intensive Process · Cognitive BPM

1 Introduction

The focus of Business Process Management (BPM) research and development was for a long time on structured processes (represented by imperative models, such as BPMN), supported directly by Process-Aware Information Systems (e.g., Business Process Management Systems - BPMS). Nowadays, however, processes are in many cases supported by a variety of applications, which can also provide data in event logs but are not process-aware. Business processes are increasingly being conducted by organizations and customers networked on social media platforms and enabled by mobile devices. So, there is a need to integrate different kinds of data sources to obtain information on the performance and compliance of such processes, as well as take proactive or corrective measures to improve them. Therefore, great value is now being credited to poorly structured processes, or the so-called Knowledge-intensive Processes (KiP), benefiting from the advent and proliferation of social media, smart devices, real-time computing and technologies for big data.

Our research investigates the origin, formalization, support and management of KiP concerning the term defined in this paper as *Knowledge-intensive Process-Aware Information System (KiPAIS)*. Accordingly, it is necessary to analyze existing data volumes from a variety of sources (including stories, e-mail repositories, sensor monitoring data, blogs and social networks) to extract and generate knowledge that can contribute to a better understanding of the events carried out (together with the context in which they were executed) and consequent modeling of a KiP in different perspectives, besides

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providing technological support to these processes. We argue that the sharing of such knowledge may result in valuable benefits to the people and organizations involved with the processes.

In addition to addressing the volume and heterogeneity (not only in the syntactical and structural levels, but also - and more important - in the semantic level) of the data, new ways of accessing the data on the Web must be considered, since current tools are mainly focused on structured data management. These issues require new research efforts towards increasing semantic precision for defining and modeling a KIP, allowing access to unstructured and contextual data that may be used as data sources for discovering a KIP, as well as measuring its performance to improve the analysis and decision-making processes. In this whole context, Cognitive Computing (as emphasized by [9]) can bring benefits from several perspectives, and might further encourage the establishment of a new BPM paradigm.

In this scenario, we propose a research framework to address specifically the following challenges: (1) eliciting and discovering KiP, and consequently defining which information is relevant to the process; (2) representing and supporting the implementation of KiP, since traditional platforms do not meet the needs of flexibility; (3) specifying a formal theory capable of explaining KiP; (4) defining a system of appropriate indicators to measure the performance of KiP, in-line with its specific characteristics.

This paper relates our research framework with Cognitive BPM, summarizing the results already obtained in light of the framework proposed by Hull and Nezhad [9], and discusses open issues and future research perspectives.

2 Research Background

2.1 Knowledge-intensive Process

The management of Knowledge-intensive Process (KiP) is an emerging field within the Business Process Management area. According to DiCiccio *et al.* [5], Knowledge-intensity in business process is characterized by the presence of collaborative interactions among participants and flexibility to perform work, making the process less predictable than a structured routine. Moreover, KiPs are processes "whose conduction and execution are heavily dependent on knowledge workers performing several interconnected knowledge intensive decision-making tasks" [5].

A KiP is essentially goal-oriented, and typically collaborative, unpredictable, not repeatable, and strongly guided by events, constraints and rules. In addition, Marjanovic and Freeze [12] investigated the relevance of knowledge creation in a KiP and argued that the expansion and use of knowledge among organizations depend on formal and informal social processes through effective communication. Examples of KiP are customer support, new product/service design, marketing, data quality management, IT governance, strategic planning. In such scenarios, existing contextual data may pose a higher influence than regular normative power in guiding the flow of activities; moreover, social interactions among stakeholders also interfere in the flow of a process, allowing (sometimes even stimulating) variants to emerge.

2.2 Cognitive BPM

Hull and Nezhad [9] state that Cognitive Computing (CC) "*can accelerate the arrival of the next generation in BPM, by enabling the development of a fundamentally new family of process abstractions that will support much richer, more adaptive, more proactive, and more user-friendly styles of process coordination*". They highlight KiP as a scenario for Cognitive BPM and explained, for example, that the separation of the process model and its instances is too restricting for cognitively-rich KiP. The authors propose a framework for a Cognitive BPM (CBPM), which is founded both on traditional BPM and Case Management contexts, as well as the new Cognitive Process Abstractions, and likewise is composed by 4 pillars:

(i) Cognitive Decision Support: CC will enable an increase in the quantity and breadth of human decisions based on an enormous volume of different types of data;
(ii) Cognitive Interaction: CC might improve interactions within processes by providing new channels and devices (including participation of cognitive agents);
(iii) Cognitive Process Learning: CC can benefit capturing and codifying process specifications, to support flexible automation;
(iv) Cognitive Process Enablement: Different types of business processes should be supported, in which the underlying process model is event-driven, and focused on ongoing goal formation, learning of relevant knowledge including constraints, planning and decision-making.

Furthermore, the authors also indicate that an appropriate process meta-model for CBPM will be based on a Plan-Act-Learn cycle. In this cycle, plans and decisions may lead to world side-effecting actions, and to learning activities, which in turn will feed into an ever-expanding knowledge base. This knowledge base could also be improved by events from the environment, and environmental reactions to process actions. And the cycle is closed once the knowledge base might lead to further decisions, goals, and plans. They argue that the high variability of Plan-Act-Learn-based process instances (which is an essential characteristic of KiP) demands new perspectives of how to support traditional BPM capabilities such as monitoring, auditing, and improvements through analytics based on history.

3 A Research Framework for KiP

We propose a research framework on KiP, which provides a basis for the lines of investigation in this domain. Although those lines could be developed independently, they all converge towards establishing the notion and components of Knowledge-intensive Process-Aware Information Systems. Those challenges are aligned with the pillars of the CBPM due to intrinsic relationships among them: (1) eliciting and discovering KiP are concerned to Cognitive Process Learning; (2) representing and supporting the implementation of KiP relate to Cognitive Process Enablement; (3) defining a formal theory to explain KiP is associated to Cognitive Process Abstractions and Cognitive Process

Interaction; and (4) defining a system of appropriate indicators to measure the performance of KiP is linked to Cognitive Process Decision-Support. Our proposals and results are summarized according to these relationships.

3.1 Cognitive Process Abstractions

Since human knowledge and involvement are key to KiP execution [10], diverse elements beyond traditional workflow-oriented processes arise, such as beliefs, intentions, desires, feelings, decisions, collaboration, and contingency events. Given that the representation of knowledge-intensive aspects is far from trivial [6], the Knowledge-intensive Process Ontology (KiPO) [6] was proposed to identify all aspects involved within a KiP. KiPO is a well-founded task ontology [8] with definitions that enable a precise interpretation and a deeper exploration of all relevant concepts comprised within a KiP.

KiPs are complex and human-centered; thus, they generate value through the exchange of knowledge among participants, often involving decision-making tasks with different alternatives for the next step in the process flow. For this reason, the human factor is the main source of complexity, especially due to the difficulty of modeling its behavior. In this challenge, two key factors are explored: (i) the difficulty of understanding the human factor, combining the advances of related research fields (such as Philosophy and Psychology) in a coherent theory to explain human behavior within a KiP, focusing on the concepts of Belief, Desire and Intention and their role in human action; (ii) a comprehensive semantic conceptualization, based on solid foundations provided by the Unified Fundamental Ontology (UFO) [8], providing the foundation to define a KiP with precise semantics, thus avoiding issues such as conceptual ambiguity and enabling its application in both modeling, discovery and execution support of a KiP. We described a formal specification of the Collaboration view of KiPO in [13].

In the most abstract level, we propose to address the problem of distinguishing instances and models by applying multi-level conceptual modeling [4] for representing elements with multiple classification levels, such as MLT (Multi-Level Theory) [4]. Moreover, we apply powertype patterns for representing KIP characterizations in KiPO [2]. In the visual representation level, we defined the Knowledge-intensive Process Notation (KIPN) [14], which addresses the representation of all relevant perspectives in KIPs, filling existing gaps in the literature with regard to integrating actors and roles into the definition of semi-structured processes, as stated by [5] as an important challenge. KIPN provides adequate support for specifying collaboration and interactions among knowledge workers in the process enactment. Moreover, KIPN also concerns the understanding of the link between the evolution of data and the decision-making process during the execution of a KIP, as well as graphically presenting specific roles that workers interpret in the execution of activities.

3.2 Cognitive Process Learning

We investigate algorithms for knowledge discovery in structured logs, as well as in texts produced within collaborative tools. The KiP elements sought are aligned with KiPO:

collaboration, decision making, business rules, human aspects and objectives, basic flow of activities. Some results have already been reported in [3, 7, 21].

In [3], we concluded that some of the discovered decisions within a KiP are candidates to become business rules that might serve as strategic knowledge for the organization and support future decisions to be made. We used decision mining techniques to discover business rules within the flow of activities of a KiP associated with a log of textual messages exchanged by process participants. Previously, we investigated the application of NLP and Text Mining techniques on emails and histories told by participants, generating representations that partially explain a KiP [21].

3.3 Cognitive Interaction with Processes

Process participants perform activities and collaborate with each other, driven by their Beliefs, Desires and Intentions (BDI); therefore, the analysis of these elements is vital to the understanding, modeling and execution support of a KiP. In [18], we proposed a method based on Speech Act Theory [1] and Process Mining to discover the flow of speech acts related to BDI from event logs, and show how this relation fosters process performance analysis. When process participants interact through natural language, the three elements are present in communication, so we analyze human conversations, supported by the Speech Act Theory.

According to [20], an illocutionary act holds the pragmatics of an utterance and is characterized by a distinct illocutionary point. We argue that illocutionary points may be correlated to BDI, which opens a path to analyzing speech acts that may represent part of human knowledge and involvement in KiPs, as previously defined in KiPO [6]. KiPO comprises precise well-founded definitions of agents and interactions among them, and how the mental moments that are inherent to them (Beliefs, Desires, Intentions and Feelings) influence (or even drive) their decisions and the control-flow of the activities executed in each instance. The challenge addressed is the difficulty to analyze how human knowledge and involvement influence a KiP execution when this information is present only in unstructured natural language resources. The first results of this work may be learned in [18].

3.4 Cognitive Process Enablement

The computational support for the life cycle of a KiP is still an open issue [5], especially considering the Plan-Act-Learn cycle. However, most modern companies have systems that (at least partially) support the execution of KiPs. For example, in a health care setting, a patient's medical record may contain information about all events, decisions made, and people involved in the treatment over time. Because of inherent flexibility and unpredictability, instances of the same KiP may be different from each other, with no clear guideline standards for a single, complete model [9]. We argue that the set of KiP execution registers (KiP log) can be considered as a process model repository so that they can be properly maintained, analyzed and explored for long periods of time by various stakeholders [19]. Therefore, a KiP repository based on KiPO and physically stored on a NoSQL DBMS platform [11] has been implemented. This solution will be incorporated into the GCAdapt environment proposed in [15], which enables the execution of processes in a flexible way through dynamic adaptation, based on contextual information and a planning algorithm.

Context plays a fundamental role in this proposal. The flexible enactment of a KiP depends on its management, comprising modeling, capturing, analyzing, and continuously updating a context model for KiP. Thus, we developed a semi-automatic method to discover contextual elements associated to a KiP. The result is a decision tree that supports the choice of variables to be monitored, which determine the need for dynamic adaptation [17]. The evolution of this environment is also concerned.

3.5 Cognitive Decision Support for Processes

KiPs, as well as other types of business processes, need to be measured to continually improve performance. This is usually done by defining, calculating and evaluating Process Performance Indicators (PPI). Performance management has already been widely discussed in the context of structured business processes [16]. Existing solutions, however, are not directly applicable to KIPs because they are not able to measure their particular characteristics. Traditional structured business processes have a predefined behavior, including possible interactions between the different participants, but this is not the case in KIPs. Participants' behavior, their interactions and decisions are not known until the execution time. That is why, in addition to the kind of measures that are commonly used such as time, cost or quality, a new set of measures that explicitly refer to characteristics that play a significant role in the KiPs is needed, and therefore impact on their performance, such as collaboration between process participants, the explicit knowledge used or the constraints and rules that drive action and decision-making during the execution of the process.

4 Towards the Definition of KiPAIS

All the results presented in the previous sections compose the research framework on KiP and are the components of a generic architecture of a Knowledge-intensive Process-Aware Information System. A KiPAIS should allow modeling, running, and monitoring a KiP based on cognitive computing techniques. Figure 1 depicts the architecture of KiPAIS and highlights the support to the Plan-Act-Learn cycle [9]. The Work System Environment (WSE) embraces BPMS, Case-Based Management systems, but also integrates any collaborative system used by an organization. The process should be modeled with an adequate notation, such as KIPN. Within the WSE, contextual information about the running instances of a KiP is continuously captured through sensors, agents or services (Context Capturing Mechanisms). The Repositories of models and instances of KiP is stored in a NoSQL graph DBMS, using a KIPO-aware schema.

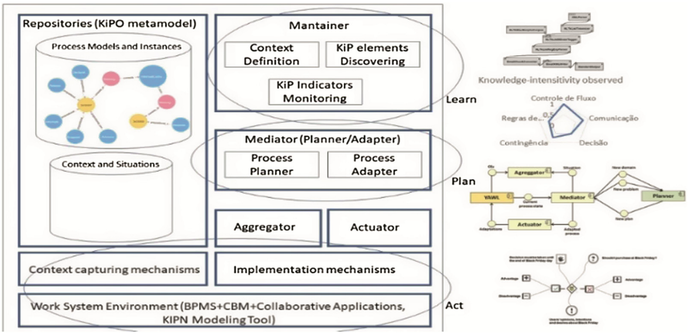

Fig. 1. KiPAIS architecture

The Mediator identifies the need for adaptation when it detects a situation that will prevent the process instance to achieve its goal. It uses intelligent behavior and decision-making support skills and is responsible for identifying possible adaptations during at runtime. When re-planning process instance, Mediator tries to fulfill goals and satisfy planning actions as its best achievement. It may find more than one possible adaptation, each of them satisfying goals in different degrees. The Actuator receives the decisions taken by the Mediator and triggers adaptations in the process instance through the Implementation Mechanisms. It involves sending commands to WSE to accomplish the necessary changes in the process instance. The Maintainer manages the context model to guarantee it will be always updated according to the current state of the KiP, and also implements the KiP PPI providing information for monitoring them, for example, in a dashboard. The right part of Fig. 1 shows some possible implementations for the Maintainer, Mediator and WSE.

5 Conclusions and Open Issues

This paper pointed research initiatives about KiP that ended up in the specification of KiPAIS, a new architecture to support the Plan-Act-Learn cycle of CBPM. Besides the results achieved so far, much work is still to be done. We list some items of an (open) agenda still based on the CBPM pillars:

- Abstractions: explore the possible associations among business rules and decision-making; establish formal relations between data elements in KiPO and domain ontologies; integrate KiPN with BPMN and commercial modeling tools;
- Learning: develop and test mining techniques to discover the diverse KiP elements; as well as perform case studies in real scenarios of big data settings;
- Interaction: investigate the BDI theory to define cognitive agents' behavior;
- Enablement: test planning algorithms to improve efficiency; implement a mechanism to capture contextual elements and complex situations, analyze multiple values and trends along time; apply mining techniques in a goal-oriented approach to continuously discover contextual elements that affect KiP;

- Decision-support: develop a method to support the definition of a system of PPI for KiP; relate the PPIs to elements of KiPO such as decision-making concepts.

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