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Cognitive Computing: What's in for Business Process Management? An Exploration of Use Case Ideas

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Abstract. Cognitive Computing promises to fundamentally transform corporate information processing and problem solving. Building on latest advances in cognitive, data, and computer science, Cognitive Computing aims to deliver autonomous reasoning and continuous learning under consideration of contextual insights and the natural interaction of humans and machines. Cognitive Computing is expected to offer significant application opportunities for business process management (BPM). While first studies have investigated the potential impact of Cognitive Computing on BPM, the intersection between both disciplines remains largely unexplored. In particular, little work has been done on identifying Cognitive BPM use cases. To address this gap, we develop an analysis framework that aims to assist researchers and practitioners in the development of Cognitive BPM use case ideas. This framework combines the most significant problem classes addressed by Cognitive Computing with central activities of the BPM lifecycle. We also used the framework as foundation of explorative workshops and report on the most interesting cognitive BPM use cases ideas we discovered.

Keywords: Cognitive Computing, Business Process Management, Cognitive BPM, Use Cases

1 Introduction

In recent years, Cognitive Computing (CC) has received increasing interest from industry and academia, as it is seen as an emerging technology tied to a new era of computing [3]. Building on the latest advances of disciplines such as cognitive, data, and computer science, CC generates context-aware insights from structured and unstructured data by leveraging autonomous reasoning and continuous learning based on an ever-growing knowledge base [11]. CC is mimicking facets of the human brain, including the ability to analyze text, images, voice, and videos in context and the interaction with humans [4]. Domains well-suited for CC are characterized by high uncertainty and knowledge-intensive problems with many potential solutions [11]. As, in the area of BPM, topics such as flexibility, context awareness, or the automation of unstructured tasks receive ever more attention [17, 18], we believe that the determining features of CC have high transformational impact on BPM research and practice in the future [8].

Cognitive BPM has been introduced by Motahari-Nezhad and Akkiraju [15] as well as Hull and Motahari-Nezhad [8]. They claim that a new BPM lifecycle, based on the *plan-act-learn* paradigm, is necessary to realize the potential of CC in the context of BPM [8]. This new BPM lifecycle shall support processes ranging from highly standardized routine processes to less predictable ad-hoc processes. Cognitive BPM involves those facets of BPM where CC offers new opportunities, either by changing the way how data is processed, presented, or how processes are designed. That said, research in this area remains scarce except for the studies of Motahari-Nezhad et al. [8, 15, 16]. Hull and Motahari-Nezhad [8] call for a framework that helps operationalize their proposed high-level Cognitive BPM lifecycle, offering tangible insights into Cognitive BPM use cases. This is the starting point of our research. We analyze the following research question: *What are use cases of Cognitive Computing in the context of BPM?*

To answer this question, we propose an analysis framework that relates the most important problem classes addressed by CC to activities from the BPM lifecycle. Our framework builds on insights into existing definitions and constitutive characteristics of CC, which we developed through a literature review. The framework is designed to help researchers and practitioners in the identification and articulation of Cognitive BPM use cases. We illustrate the use of our framework by outlining a series of exemplary Cognitive BPM use cases. In line with the explorative nature of our study, these high-level use case ideas should be seen as a starting point for a community-wide discussion about how to exploit the technological opportunities of CC for BPM.

This paper is organized as follows: In section 2, we lay the foundations of our analysis framework by developing a definition of CC and by summarizing ways of structuring the BPM discipline. In section 3, we introduce our analysis framework. We also report on the exemplary Cognitive BPM use case ideas we identified. We conclude by summarizing our findings, by stating limitations, and by pointing to further research in section 4.

2 Domain Background

2.1 Cognitive Computing

CC is an emerging field without a commonly accepted definition [8]. Attempts to define CC mainly occurred in industry [4, 6, 12]. Thus, there is a need for a common definition synthesizing technology- and domain-specific interpretations. In this section, we summarize CC definitions we found in the academic and practitioner-oriented literature. On this foundation, we derive constitutive characteristics and a working definition of CC. As CC has multiple origins, the term 'Cognitive Computing' has been defined and interpreted differently. Our literature review yielded 26 definitions. In two workshops, we discussed and selected the eight most comprehensive definitions from both academia and industry: academic publications [14, 19], books [7, 9], industry reports [11, 12], and interpretations from a consortium of researchers and practitioners dedicated to CC [4, 6]. While analyzing less technical definitions, we identified four topics that reoccurred frequently. These topics are: interaction, context awareness, reasoning, and learning. Based on this review and in line with extant literature, we define the constitutive characteristics of CC as follows [4, 10]: (1) *Interaction*: Natural communication between humans and machines as well as among humans, (2) *Context awareness*: Identification and extraction of contextual information from structured and unstructured data at large scale, (3) *Reasoning*: Generation, testing, and assessment of hypotheses based on context information and past learnings, and (4) *Learning*: Continuous expansion of the knowledge base by incorporating learnings of prior decisions and reasoning. Subsuming, we define CC as follows for the purposes of our study: *Cognitive computing is an umbrella term for new problem-solving models that strive for mimicking the cognitive capabilities of the human mind by autonomously reasoning and learning based on incomplete structured and unstructured contextual data, and through natural interactions with humans and machines*.

2.2 Business Process Management

As BPM is a vital dimension of our framework, we investigate which approaches have been proposed to structure BPM. The most common approaches are lifecycle models and capability frameworks [20]. We focus on these comprehensive structures, not on individual methods or tools to ensure a holistic picture of BPM. Lifecycle models structure BPM along the (management) activities that occur during the lifecycle of a business process [20]. Although there are many conceptualizations of the BPM lifecycle, the involved activities vary only slightly. Most BPM lifecycles cover the following activities: process design and modeling, process implementation and execution, process optimization and improvement [13]. In their recent work on Cognitive BPM, Hull and Motahari-Nezhad [8] propose a shift in the BPM lifecycle paradigm, anticipating the characteristics of CC in the context of BPM. Their Cognitive BPM lifecycle includes the activities ‘plan’, ‘act’, ‘monitor’, and ‘analyze’. In this new BPM lifecycle, the differentiation between the activities of the traditional BPM lifecycle gets blurred. The iterative planning, continuous monitoring, integrated analysis, and refinement of processes are also supposed to blur the separation of process models and process instances.

3 Analysis Framework and Cognitive BPM Use Case Ideas

Below, we introduce our analysis framework for Cognitive BPM use cases ideas. We introduce our framework in section 3.1 based on the literature review presented in section 2. Having used our framework as foundation for explorative workshops, we also report on the most interesting use case ideas we discovered in the sections 3.2 to 3.5.

3.1 General Setting

Our analysis framework comprises two dimensions: a BPM and a CC dimension. When conceptualizing the BPM dimension, we had to choose between BPM capability frameworks and BPM lifecycle models. For this study, we selected lifecycle models as they are very tangible, reflecting how tasks within the lifecycle of a process can be supported by CC. BPM capability frameworks are more fine-grained and also include elements (e.g., people, or culture) that can only indirectly be enhanced by emerging technologies such as CC. In section 2.2, we introduced the traditional BPM lifecycle and the Cognitive BPM lifecycle as proposed by Hull and Motahari-Nezhad [8]. As our framework aims to assist in discovering Cognitive BPM use case ideas, we adopted the traditional BPM framework for conceptualizing the BPM dimension. Reasons are that the traditional BPM lifecycle is very mature and captures the contemporary conceptualization of BPM from a lifecycle perspective. The Cognitive BPM lifecycle, in contrast, focuses more strongly on the target state after the traditional BPM lifecycle has been transformed. This makes the Cognitive BPM lifecycle less suitable for the purposes of our study. Following Macedo de Morais et al. [13], we cluster the activities included in the BPM lifecycle into *definition and modeling*, *implementation and execution*, *monitoring and controlling* as well as *optimization and implementation*.

When conceptualizing the CC dimension, we used the working definition and constitutive characteristics from section 2.1. On this foundation, we derived the most important problem classes addressed by CC, i.e., *knowledge-intensive problems*, *human-computer interaction*, and *human collaboration*. Grounding this dimension on concrete CC functionalities and technologies would have been too fine-grained for developing Cognitive BPM use cases, as a previous version of our framework showed. Knowledge-intensive problems require extracting information, weighing its relevance and validity as well as generating and testing hypotheses. As noted by Aamodt [1], this includes sub-processes of inferring context, reasoning, and learning. These steps match three constitutive characteristics of CC. Building on the 'context awareness' and 'learning' characteristics, CC extracts knowledge and context from structured and unstructured data and continuously feeds its knowledge base with new insights. Human-computer interaction as a problem class includes several key elements such as the understanding of language, perception of intention, and domain knowledge [5]. The constitutive characteristic 'interaction' highly contributes to this problem class. Leveraging contextual information about humans to develop human-like empathy and communications skills, CC interacts with humans in a natural way, bringing advances in the field of human-computer interaction [4, 11]. The third problem class human collaboration is related to human-computer interaction. Perceiving and understanding humans, CC improves human collaboration by providing tools that can be adapted to the context of participants [2]. Interaction as the most contributing characteristic of these two problem classes is supported by the other characteristics, as understanding human language and intentions comprehensively requires context-based information and reasoning abilities. The 'learning' characteristic further improves the accuracy of interactions. Table 1 shows our analysis framework that puts the most important problem classes addressed by CC and the key activities of the BPM lifecycle into perspective. Below, we outline the initial Cognitive BPM use case ideas that we identified structured along the BPM dimension of our framework.

Table 1. Analysis framework of Cognitive Computing in the context of BPM

Activities of the traditional BPM lifecycle	Cognitive Computing Problem Classes		
	Solutions of knowledge-intensive problems (A)	**Human-Computer Interaction (B)**	**Human Collaboration (C)**
Definition & Modeling (1)			
Implementation & Execution (2)			
Monitoring & Controlling (3)			
Optimization & Implementation (4)			

3.2 Use Case Ideas for 'Definition & Modeling'

Discover process models from unstructured data (A1). This use case idea refers to the automated discovery of process models from structured and unstructured, potentially non-process-related, data. The data processing features of CC could enhance process mining techniques to leverage unstructured data (e.g., emails, conversations, or documents). Thereby, CC uses contextual knowledge to generate hypotheses about new process models. *Example*: Suggestion of a new process model based on concepts extracted from regulatory documents.

Design and adaption of configurable process models considering organizational context (A1). CC could help derive context-specific models from configurable or reference process models. Based on the organizational structure, domain, available resources as well as other processes and dependencies, CC could automatically suggest configured process models by applying reasoning and learning techniques. *Example*: Adaptation of a company-wide invoice approval reference process for a department where invoices from certain partners require special approval. Based on its knowledge about the department's context, CC is aware of this requirement and adapts the reference process automatically.

Interactive process design support (B1). Building on information about the process (e.g., goal, purpose, stakeholder, resources), organizational context (e.g., industry, regulations, other processes, best practices), and information about the process modeler (e.g., experience, skills), CC could suggest process steps to be included, data elements to be used, role assignments to be made, and connections with other processes to be created. In a responsive manner, CC would react to the modeler's input. *Example*: Assistance in designing a customer support process. After a customer inquiry is categorized, CC may suggest modeling an XOR split to make a decision whether to automatically respond to this inquiry or to assign a user. Thereby, CC considers existing automated response systems within the organization.

Visualization of process models considering different stakeholders (C1). Different stakeholders and process model users may have different experience and skill levels. CC could incorporate the context and knowledge about users to evaluate the effectiveness of a process model's visualization. If the model does not seem clear to the user, CC could suggest a different visualization form. CC may support collaboration among humans by translating different user perspectives. *Example*: For a management meeting, a complex process model captured in BPMN is presented as a simple flowchart, including the most important process elements. Thereby, CC perceives information about the participants of the meeting and extracts important process elements according to participants' background knowledge and preferences.

Support in process design collaboration (C1). Cross-organizational process modeling involves linguistic barriers (e.g., different vocabularies and semantics) as well as coordination effort (e.g., time, distance). CC could support the translation among the involved process modelers by automatically designing a meta model that abstracts from the organization- or domain-specific context. CC could identify dependencies between departments or organizations at the process level. *Example*: In a joint venture, two organizations align their procurement processes. CC may support this by creating a meta model for mapping organization-specific names, abbreviations, systems, roles, and activities. Thereby, CC would leverage knowledge about both organizations and the domain-specific context.

3.3 Use Case Ideas for 'Implementation & Execution'

Dynamic resource allocation at runtime (A2). Dynamic resource allocation considers several criteria. It includes the allocation of individual tasks to humans or software services based on availability, capacity, workload, human's mental state (e.g., stress, concentration) and skills as well as context. Moreover, this mechanism may account for deviant behavior via dynamic re-planning or choosing alternative suitable process variants. *Example*: Resource allocation in a call center. Based on the language, a French-speaking caller with a complex problem is allocated to an experienced agent who can handle the problem due to his experience and mental state. Thereby, CC obtains contextual insights about the caller and his inquiry by analyzing the problem statement. CC may also redirect all inquiries that do not require human skills to an automated messaging system (e.g., chatbot) to handle peak loads.

Automatic execution or suggestions of next best task at runtime (A2). At runtime, CC could observe the execution of a process and predict the next possible tasks by analyzing structured and unstructured data. Based on these insights, CC may reason about each step in a process and propose the next best task. *Example*: In an automated process, a chatbot initially handles all customer inquiries. Based on an analysis of social media posts, CC detects negative feedback regarding a specific product of the company. To prevent damage to the company, CC suggests handling all inquiries regarding that product manually by customer service due the empathy of human agents.

Interactive task assignment assistant at runtime (B2). In addition to the use case idea above, CC could work as a personal assistant [16]. Accounting for their mental state, experience, and skill set, CC may guide human process participants through their worklist to effectively and efficiently meet process goals as well as performance targets. Considering that users interact with their cognitive assistants about their work schedule, this covers conversations about the scheduling, prioritizing, timing, skipping of tasks, or requesting additional auxiliary tasks. CC is responsive and learns the personal preferences over time. *Example*: User input: "What are tasks of higher priority today?". A cognitive assistant may prioritize tasks for investigating fraudulent payments leveraging knowledge about specific payment terms. As sensor data measures a rise of the user's stress level, complex fraud is automatically forwarded to a less busy user.

Support in decision-making at runtime (B2). Regarding decisions that require the analysis of large datasets and expert knowledge, CC could support decision-makers with contextual information and hypotheses about the decision at hand or relevant information. CC could also anticipate user input by adjusting context and iterative reasoning. In this case, CC heavily relies on its continuously expanding knowledge base, but also on perceiving the context of the decision process. *Example*: In the process of running a marketing campaign for a new product, CC may suggest different methods and propose interpretations of the campaign results by inferring the context and reasoning about structured and unstructured data (e.g., comments on social media).

Dynamic suggestions of collaboration at runtime (C2). Following up on the previous use case idea, CC could support decision-makers by automatically matching co-workers with complementary knowledge and experience to collaborate on a task. Moreover, CC could help match co-workers regarding their skill sets as well as personality. Thereby, CC extracts characteristics of workers from sensor data, written text, and past collaborations. *Example*: During a human resource process, applicants and interviewers are automatically assigned to each other based on same personality type and knowledge backgrounds in order to create a fair common ground.

3.4 Use Case Ideas for 'Monitoring & Controlling'

Automatic anomaly and deviant behavior detection at runtime (A3). This use case idea builds on process mining and predictive analytics. Reasoning about and learning from structured and unstructured data that is directly or indirectly produced during process execution (e.g., text, documents, sensor data, log data), CC could automatically detect and predict process anomalies and deviant behavior at runtime. Based on this ability, CC may consider actions of exception handling by automatically changing or stopping a process instance or notifying a process manager or other authorities for intervention. *Example*: In a customer service scenario, CC automatically checks the conformance of customer inquiries by identifying insufficient responses before being sent out. Therefore, CC matches topics of the inquiry and the response messages. As this is a deviant behavior in the process, CC warns a customer service worker accordingly.

Conversation-like process monitoring queries (B3). CC could support humans by providing insights into currently running processes and concurrent instances. In an interactive way, CC may process natural language queries and respond accordingly. Further, CC could reason about the conversation and respond in an intelligent way by interpreting requested data and suggesting further interesting insights. CC could also learn process-specific user preferences. *Example*: User input: “return all running processes that contain activities that need to be executed by someone with the role manager and that are exceeding the planned processing time”. CC translates this natural language query and responds with the requested information. Additionally, it automatically informs the user about a specific process step that could harm the organization to a great extent if it is not investigated.

3.5 Use Case Ideas for ‘Optimization & Improvement’

Proactive identification of process improvement opportunities (A4). CC could proactively help identify process improvement opportunities by analyzing process anomalies, deviant behavior, external information (e.g., best practices, novel designs), and insights from automated processes. Thereby, CC would rely on its ability of inferring the process context, continuously learning, and generating hypotheses. *Example*: In an organization, the first-level support for the order process is currently performed by a human process participant. CC perceives and automatically learns the steps of action of the first-level support at large scale. Thus, CC suggests the automation of this process as CC produces the same outcome at a shorter runtime.

Identification of need for training (B4). Accounting for the performance, skills, experience, and mental state of a process participant over time, CC could automatically identify the need of training. It may suggest and interactively guide process participants through individual training. Thereby, the progress and learning curve is dynamically monitored and the training is adjusted accordingly. *Example:* CC detects that a user’s performance at investigating claims at an insurance company falls below the performance of his peers (e.g., same age, education, task assignments). Identifying the lack of knowledge about a specific type of claims, CC automatically suggests a training on the law underlying this type of claims.

Support of collaboration between process managers and participants (C4). CC could support process managers and participants in their collaboration to analyze and improve processes. As both parties might not have the same skills and background, CC could dynamically translate suggested process improvements at the process participant level (e.g., improvement of a distinct task) to the broader perspective of a process manager overseeing a portfolio of processes. *Example*: A process participant proposes to perform several tasks concurrently instead of sequentially. Thereby, CC automatically translates this idea into the process manager’s perspective, checking the consequences of this idea regarding dependencies with other processes as well as compliance with regulations and company governance. It may also suggest a counter-proposal that is translated to the process participant’s perspective again.

4 Conclusion, Limitations, and Further Research

In this study, we investigated the impact of CC on BPM. Our contribution is threefold: First, we derived constitutive characteristics of CC (i.e., interaction, context awareness, reasoning, and learning) based on extant literature and proposed a corresponding working definition. Second, we proposed an analysis framework that aims to assist researchers and practitioners in the systematic derivation of Cognitive BPM use case ideas. This framework builds on the BPM lifecycle and essential problem classes addressed by CC, i.e., knowledge-intensive problems, human-computer interaction, and human collaboration. Third, we reported on interesting high-level Cognitive BPM use case ideas using our framework as a foundation. We identified a large potential for CC in the BPM domain covering all activities of the BPM lifecycle and entailing a higher level of automation in BPM. This increasing level of automation enabled by CC also fosters the human centricity of BPM, as CC with its characteristics promotes user-aware assistance systems and a natural interaction between humans and BPM systems. In general, we expect it to play a central role for next-generation BPM systems.

Our study is beset with limitations that call for further research. First, we consider activities of the BPM lifecycle and CC problem classes in an aggregated view. To take a more detailed perspective on the impact of CC on BPM, further research is required that caters for a different and more fine-grained view on the BPM lifecycle. For a more detailed perspective on CC, further research could investigate more technical details of CC such as concrete CC functionalities or technologies. Second, our explorative approach of discovering use cases ideas comprises limitations. Our goal was to compile an initial set of Cognitive BPM use case ideas, motivating researchers and practitioners for further investigations. We do by no means claim that our list is exhaustive. To further develop and validate this initial compilation, we recommend conducting Delphi studies, focus groups, or expert interviews leveraging the knowledge of many BPM and CC experts. Third, in this study, we have not yet conducted a detailed investigation of the identified use case ideas, neither from a technical nor from a business case perspective. We call for further research in close collaboration with industry to probe into the feasibility of our and, of course, new Cognitive BPM use case ideas. In an ongoing research project, we are currently working on a reference architecture for Cognitive BPM and software prototypes of selected use case ideas.

Despite these limitations, we believe that our analysis framework and the exploration of initial use case ideas are first steps toward more grip on Cognitive BPM. With this study, we invite fellow researchers and practitioners to challenge and extend our ideas and help explore the technological opportunities of CC for BPM.

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