Leveraging Augmented Reality to Support Context-Aware Tasks in Alignment with Business Processes

Gregor Grambow, Daniel Hieber, Roy Oberhauser, Camil Pogolski

Aalen University, Aalen, Germany

Corresponding author: Roy Oberhauser, roy.oberhauser@hs-aalen.de
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Abstract

The seamless inclusion of Augmented Reality (AR) with Business Process Management Systems (BPMSs) for Smart Factory and Industry 4.0 processes remains a challenge. Towards this end, this paper contributes an approach integrating context-aware AR into intelligent business processes to support and guide manufacturing personnel tasks and enable live task assignment optimization and support task execution quality. Our realization extends two BPMSs (Camunda and AristaFlow) and various AR devices. Various AR capabilities are demonstrated via a simulated industrial case study.

1. Introduction

As Industry 4.0 digitalization grows, both business and production processes and associated IT automation play a significant supporting role for increasingly complex scenarios. Furthermore, the integration of industrial augmented reality (IAR) to support human tasks in production processes has remained limited, as BPMS have hitherto not directly supported nor integrated AR. In prior work (Grambow, Oberhauser, & Reichert, 2010, 2011), we developed an approach for contextual process management tailored towards software engineering (SE) processes, while prior extended reality work includes (Oberhauser & Lecon, 2017), which focused on the potential of virtual reality for addressing certain SE-related challenges. This paper contributes an approach for integrating context-aware AR into intelligent business processes, enabling process-centric and context-aware AR support for manufacturing personnel tasks to support assignment optimization and execution quality. Our realization via two commercial BPMSs shows its feasibility.
The paper is structured as follows: Section 2 describes related work, and Section 3 describes our solution concept and realization. Section 4 provides an evaluation, followed by a conclusion and future work.

2. Related Work

In (Blattgerste et al., 2017), AR glasses provide mobile assistive instructions, but was largely restricted to one concrete problem or scenario rather than a generic business process. BPMN4SGA (Vogel & Thomas, 2019) integrates Smart Glasses as a BPMN extension, but primarily for documentation purposes rather than actionable AR content. In our approach, AR Actions are modeled and implemented via predefined AR templates containing attributes for nearly all BPMN elements, with the AR application interpreting the templates and sends feedback to the BPMN modeling application, avoiding implementing or syncing steps with the BPM engine. SenSoMod (Dörndorfer et al., 2018) adds context-awareness to conventional non-production applications like email, calendar, etc. (Gronau & Grum, 2017) combined the Knowledge Modeling and Description Language (KMDL) with AR and projected sensor data and process step association onto machines, but it lacks concrete tailored task guidance. BPMN4CPS (Graja et al., 2016) combines BPMN with cyber-physical systems, adding resources and context data to a business process for increased automation, but it does not integrate AR directly. HoloFlows (Seiger et al., 2019) is an AR process modeling approach for the Internet of Things (IoT), utilizing a simple state-machine and custom notation that lacks BPMN support and integration with mature BPMS - vital for industrial settings.

3. Solution and Realization

As shown in Figure 1a, our overall PARADIGMA solution addresses context-awareness and AR integration within business processes, including the user's positional data and objects of interest at that location, gathering AR-based content input from users, integrating AR-based user choices into the local process context, and providing AR-based guidance and prioritizes and optimizes task assignments based on context (detailed in Grambow et al., 2021a). Our logical architecture is shown in Figure 1b, the front end is the top layer which supports our AR app, while a BPMN app supports the modeling of AR processes with AR support (detailed in Grambow et al., 2021b). The AR app contains the 3D models, animations, videos and images that will be displayed in AR. The apps communicate with the PARADIGMA Backend via REST calls, primarily using JSON-based content. This Backend, in turn, can integrate with any BPMS via REST APIs, currently integrated with either Camunda or AristaFlow. While our solution considers many more facets, this paper primarily elucidates the AR relevant aspects.

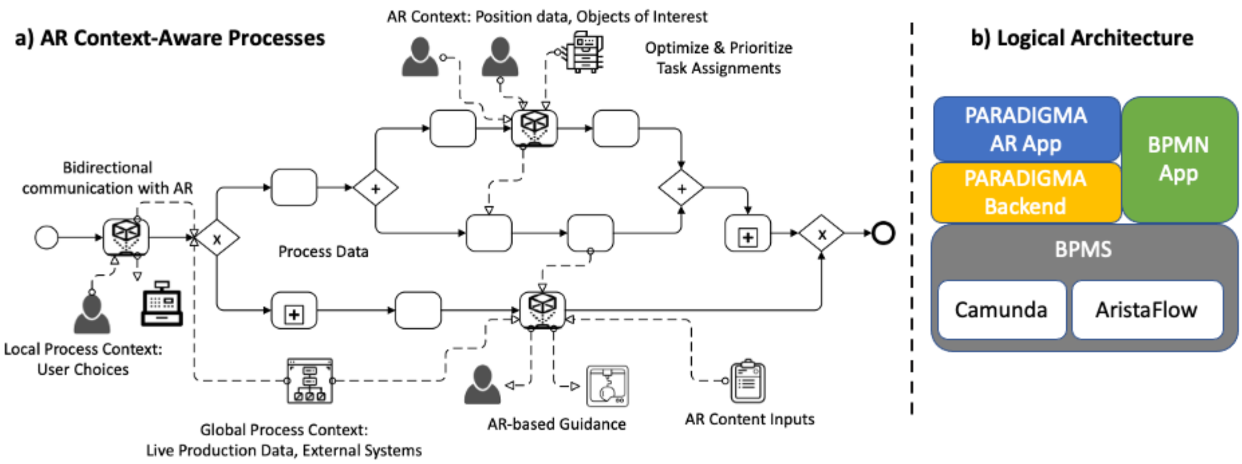

Figure 1: PARADIGMA Solution Approach: a) AR Context-Aware Processes and b) Logical Architecture.

For BPMN compatibility, our BPMN elements are not directly distinguishable from normal BPMN elements without AR Actions. During modeling the distinction is made by viewing the Variables Tab for a BPMN element in the corresponding BPMN modeling application. As shown in Figure 2, a modular system of AR components supports various AR content-specific types, some of which we highlight below.

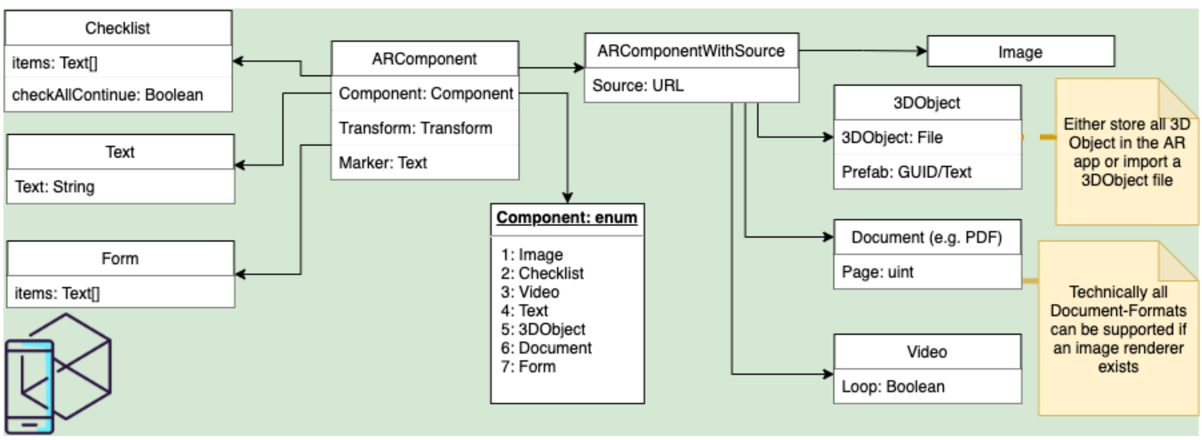

Figure 2: Overview of the currently implemented AR Modules.

The AR Video / Image module supports video (with an alpha channel) or image (with an alpha channel) placement in the AR world. The AR Checklist module supports task quality via checklists in AR. The 3D Overlay module renders and positions 3D virtual objects in space.
The AR app was realized with Unity 2020.3.8f1 with AR Foundation, ARCore XR Plugin, ARKit XR Plugin, and Magic Leap XR Plugin. It integrates REST call interaction containing JSON content with the PARADIGMA backend (and implicitly BPMS) and handles the placement of objects in the virtual AR space.

4. Evaluation

Due to current restrictive COVID-19 industrial access, we simulated various industrial scenarios in an analogous academic setting. Due to space constraints, only our machine modification scenario is described here. The BPMN model for our case study is shown in Figure 3. For this scenario, an additional part (PCI card) is added to a PC, analogous to adding or replacing a machine part in an industrial scenario. We tested our system with a tablet (fixated by a hands-free tool) since not all workers will have access to AR goggles, and a Magic Leap 1 as shown in Figure 3a and using its pointing device in Figure 3c. As Figure 3h shows, checklists are spatially anchored (static) to ease reading, pointing, and checking; settings (top left) and a task list (top right) are accessible; the active task (green) is shown with a white checkbox to its left to permit ending the task (even if some items remain unchecked).

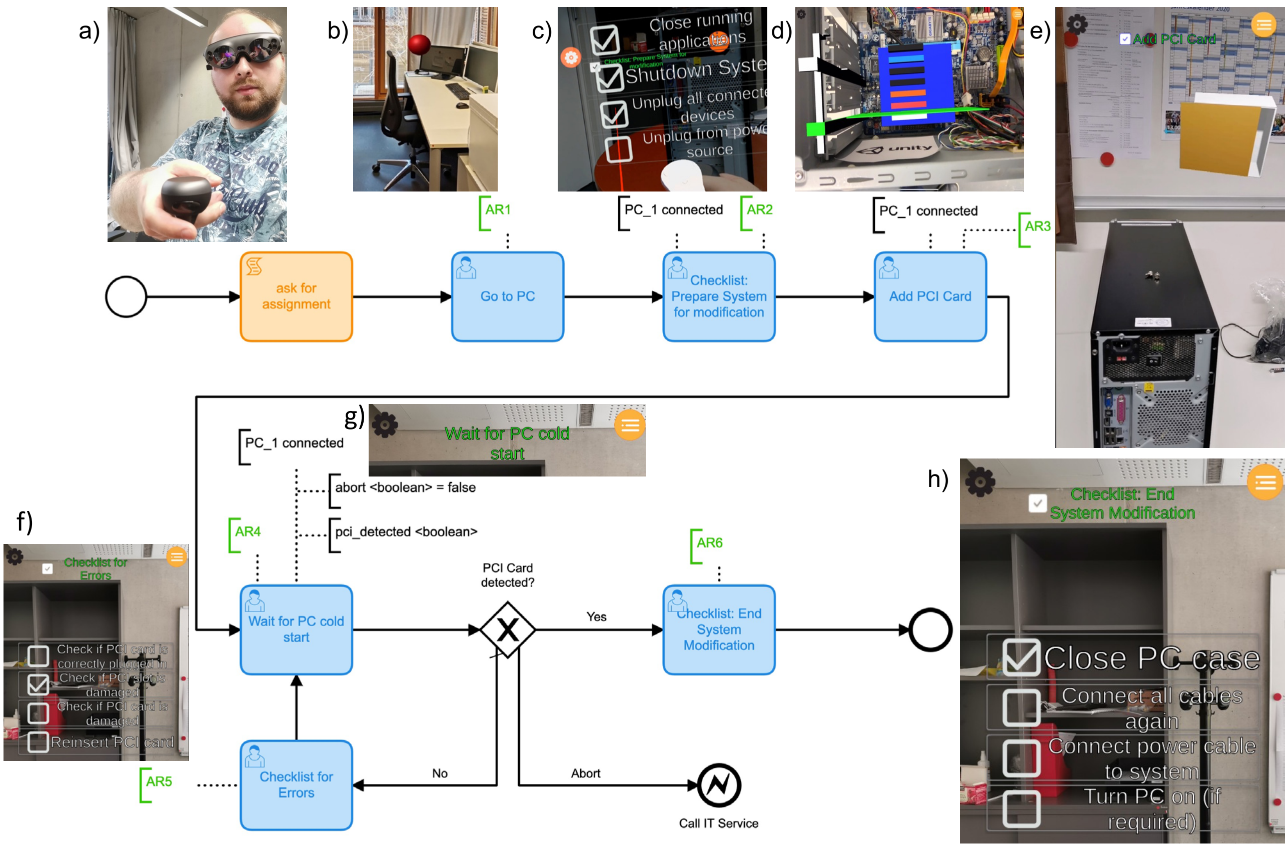

Figure 3: BPMN Model in Camunda Modeler annotated with AR tasks in green; a) Magic Leap b) AR navigation support c) AR Checklist for task preparation d) AR overlay e) AR video guidance f) AR error checklist g) AR PARADIGMA backend automatic machine sensor detection h) AR process completion checklist

The scenario process (Figure 3 Camunda BPMN with AR annotations in green) consists of the following:

1. "ask for assignment" activity: the PARADIGMA-Backend determines the optimal worker for an assignment via our backend IAC (Intelligent Assignment Component) and assigns it to that worker.
2. User is notified of an assignment in the AR App: The upper right “Task Button” displays a red dot.
3. "Go to PC" [AR1 task]: red spheres (anchors) are used to guide the User to the destination (Figure 3b).
4. [AR2] Displays a checklist (Figure 3c) for system hardware modification preparation (Figure 3d).

5. [AR3] An AR-Video-Overlay is shown on how to open up a PC case (Figure 3e). Once the marker inside the PC is scanned, the video stops and a 3D PCI Card and mainboard overlay is shown (Figure 3d). The user ends the AR task by selecting the checkmark next to the active task.
6. [AR4] The user waits (Figure 3g) for PARADIGMA context sensors to detect PC and PCI card.
7. [AR5] If undetected or a timeout occurs, an Error Checklist is shown (Figure 3f) and [AR4] is repeated.
8. [AR6] PCI Card was "detected" so the completion checklist (Figure 3h) is shown. Once all items or task is checked, the activity and process are ended and PARADIGMA provides the next assignment.

5. Conclusion

Towards improving IAR and Smart Factory and Industry 4.0 process integration, we contributed a context-aware approach for IAR modeling and integration that aligns business processes with worker situations and global and local industrial context. It contextually integrates process-based guidance and support for manufacturing personnel tasks, live task assignment optimization, and improved task execution quality. Our realization via integration with two BPMSs and various AR devices showed its feasibility. Our evaluation case study demonstrated primary IAR capabilities. Future work includes automatically determining the expertise of an AR user (e.g., based on errors and/or performance and guidance usage) and auto-adjusting the guidance appropriately; integrating additional hand-tracking and gesture detection mechanisms; improving AR marker recognition; supporting manual process task jumps to previously completed activities; supporting task preview mode; addressing AR darkness/light condition sensitivity for object positioning; and a comprehensive empirical study in an industrial setting.

6. Acknowledgments

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