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Leveraging Apps in Manufacturing. A Framework for App Technology in the Enterprise

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Abstract

Apps on mobile devices like smartphones have become the core of the digital life of consumers. Apps are used, e. g., for shopping or communicating in social networks. Recently, apps are gaining more and more attention in enterprises as enabler for agile process optimization. In this article, we discuss the potentials and challenges of exploiting this technology with a focus on the manufacturing industry. We come up with a framework for apps in manufacturing companies and identify major areas that need further investigations to fully leverage apps. Moreover, we present existing and novel apps across the product life cycle.

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Keywords: Enterprise Apps, App Infrastructure, App Development, App IT Architecture, App Security, App Privacy

1. Introduction

Nowadays, nearly 70% of all Internet users access the Internet using mobile devices like smartphones and tablet PCs [1]. Apps on these devices are becoming the core of the digital life of consumers and are used, e. g., for communication in social networks as well as mobile banking and shopping. Up to now, the Apple App Store counts more than 25 billion app downloads [2]. Due to consumerization – that is, consumers bringing their private mobile devices to work – and the increasing need for employee mobility and flexibility, apps are gaining more and more attention in business environments as novel enabler for process optimization [3].

Many existing enterprise apps (EA) focus on personal information management (PIM), e. g., mobile email, or mobile sales and service processes. In contrast, there is only a little number of EAs for processes in the manufacturing domain [4], e. g., for process design and production execution. Moreover, the goal-oriented development and use of EAs poses new challenges to enterprise IT, corporate management and organizational structures such as aligning apps and business needs [5] or managing heterogeneous mobile platforms [6].

In this article, we present a conceptual framework for EAs in manufacturing companies. It comprises five essential components for an EA strategy to fully leverage EAs, namely EA portfolio, EA IT architecture, EA development, EA infrastructure and EA security and privacy. That is, we structure the state of the art and outline further research issues with respect to EAs in manufacturing companies.

The remainder of this article is structured as follows: In Section 2, we define and classify apps and describe general opportunities and challenges. Next, Section 3 comprises our framework. Exemplary EAs as well as novel fields of application are presented in Section 4. We conclude in Section 5 and highlight future work.

2. Foundations of Enterprise Apps

2.1. Definition and Classification

The term “app” was originally coined by Apple when they launched their App Store as a centralized download platform for applications on the iPhone in 2008. Up until now, there is no clear common definition of apps, neither in literature nor in practice. In the broader sense, apps stand for any form of application on a computing device, no matter whether on a smartphone or a tradi-

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tional PC. E. g, in the terms of Microsoft, all applications for Windows 8 provided by the Windows Store are called apps [7]. In the stricter sense, apps refer to applications for novel mobile consumer devices with a touchscreen, especially smartphones and tablet PCs. In this article, the term "app" is used in the stricter sense, whereas applications comprise all forms of executable programs including browser-based web applications. We focus on consumer devices and corresponding mobile platforms, such as the Apple iPhone and Apple iOS, because app ecosystems are a consumer-driven phenomenon [6]. That is, proprietary domain-specific mobile devices, e. g., hand-held scanners used in logistics, are out of scope. The same applies to traditional mobile consumer devices without touchscreens, e. g., laptops.

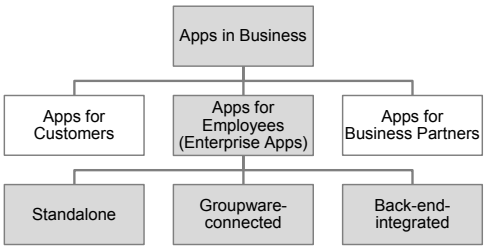

Fig. 1. Classification of apps in business

Regarding apps in business, we differentiate three main types according to the target group of users (see Fig. 1): There are apps for customers, which focus on customer-company interaction or customer-product interaction. Examples are apps for buying tickets or controlling a car. In addition, there are apps for employees, which support business processes in the company. Examples are apps for mobile customer relationship management (CRM) to prepare proposals on-site at the customer. Finally, there are apps for external business partners, which support interorganisational interaction, e. g., in supply chains. In this article, we focus on apps for employees encompassing personnel on all hierarchy levels, e. g., workers and executives. We call these apps enterprise apps (EAs).

With respect to the degree and complexity of integration in the enterprise IT infrastructure, we observe mainly three general sorts of EAs: Standalone EAs are not integrated with a server-side back-end, with application logic and data storage residing completely on the mobile device. An exemplary standalone EA may be used for calculating typical engineering formulas, such as energy consumption of a machine based on given input parameters. Groupware-connected EAs are linked with standard enterprise groupware systems, e. g., Microsoft Exchange, to provide PIM services, e. g., mobile emailing and task management, for support of unstructured business processes. Finally, back-end-integrated EAs are tightly integrated with the company's back-end of enterprise IT systems supporting structured business processes. Exemplary EAs may provide mobile enterprise resource planning (ERP) or CRM. Back-end-integrated EAs are the most complex type because enterprise IT landscapes are typically coined by a wide range of historically evolved heterogeneous and often proprietary IT systems [8].

2.2. Opportunities and Challenges

In contrast to traditional mobile applications in the context of mobile business [9], which run on laptops or Personal Digital Assistants (PDAs), the novelty and potential of EAs is based on the following key characteristics, that is, success factors, of smartphones and tablet PCs in combination with suitable apps:

- "Anywhere & Anytime": Apps can be used without traditional restrictions on time and place in an always-on and always-online fashion. There is neither a need for a desk pad nor for a time-consuming starting and booting of the device. Apps may be started ad-hoc on the go within seconds. Moreover, new apps are centrally provisioned in catalogue-like manner and can be easily installed by the user without the need for a complex setup process.
- "At your fingertips": Apps provide support for very targeted tasks, following an intuitive and easy-to-use touchscreen-based interaction paradigm. That is, apps are tailored towards specific functions, such as controlling of goods received, and make use of context information , e. g., location data, to realize a personalized and easy task handling. These apps are also called role-based apps [10]. A role-based app focuses on a single function being highly aligned with a specific role of an employee in a process.

Hence, EAs, especially back-end-integrated EAs, have a great potential for value generation as they support, on the one hand, the seamless integration of mobile workers in business processes [6], e. g., by digitalizing of previously paper-based mobile data acquisition tasks. On the other hand, they enable the mobilization of formerly fixed process steps, thus, leading to a reinvention of the entire process, e. g., by allowing production supervisors to monitor production from out-of-office.

Based on a literature review, especially [3, 4, 6, 11, 12], and industry interviews in a large German car manufacturing company, we identified the following core challenges regarding EAs:

- Identification of fields of application and concrete use cases for EAs: Potential business processes or tasks for which EAs should be developed have to be identified.
- Advancement of IT infrastructure: Existing historically evolved IT infrastructures have to be advanced to provide a unified EA-compatible abstraction layer.

- Standards for development: The effective development of EAs requires manufacturing-specific frameworks and standards. e. g., for data models and interaction paradigms.
- Management of platforms and apps: Different mobile platforms, such as Google Android and Apple iOS, as well as varying devices, e. g., smartphones and tablet PCs, require a unified device management and a centralized method for the distribution and update of EAs.
- Ensuring security and privacy: High data security requirements in the manufacturing industry as well as employee privacy regulations require novel approaches adapted to consumer mobile devices.

3. Enterprise App Framework

Our EA framework addresses the above core challenges to leverage EAs in manufacturing companies. It defines five central conceptual components for an EA strategy. For each component, we analyze the state of the art and identify major research areas that need further investigation. A general overview about enterprise mobile strategies is given by Clevenger [4]. In this article, we focus on open issues especially with respect to manufacturing companies and propose initial stages for solutions.

3.1. Enterprise App Portfolio

To fully realize the business potential of EAs, a suitable EA portfolio combining the company's business needs and the key characteristics of apps (see Section 2.2) is a central success factor, not only for manufacturing companies [4]. In general, we differentiate two approaches to deduce a portfolio of EAs for a company.

In the business-process-driven approach, the analysis and reorganization of business processes provide the basis for the definition of suitable EAs. The general goal is to align business and IT, that is, business processes and EAs, by identifying and evaluating process-oriented use cases and fields of application for EAs in a top-down manner. Hence, traditional concepts from the research field of information systems as well as business process management, e. g., business process reengineering [13], have to be adapted and concretized with respect to EAs and mobile devices. On the one hand, mobile business processes have to be analyzed and decomposed in sub processes with mobile process steps [14]. On the other hand, business processes with fixed process steps that benefit from mobilization have to be investigated. These two procedures reveal an amount of process steps relevant for EAs. Then, single-function tasks as part of these process steps are identified. They have to be structured and prioritized, e. g., according to their frequency of execution, the amount of data input or their business criticality level. On this basis, corresponding role-based apps can be defined. A systematic methodology has to detail and integrate all these aspects to deduce a structured EA portfolio aligned with business process needs.

In contrast to the classical top-down business-process-driven approach, which originates from the development of large-scale enterprise software systems, the user-driven approach [11] follows a bottom-up paradigm for the generation of EAs. That is, the users themselves generate EAs based on their needs for single-function software tools in their daily work. Either, non-technical employees order a corresponding EA based on their requirements from the IT department or technically skilled employees develop their EAs on their own. This leads to dramatic organizational and technological changes in enterprise IT as it requires suitable development support and a corresponding infrastructure for app deployment as well as novel security concepts (see Sections 3.3, 3.4, 3.5).

The user-driven approach focuses on the best fit of EAs and individual employees' needs based on a quick app-oriented tool development and, thus, supports enterprise transformability. Yet, it involves the danger of a heterogeneous portfolio of possibly low-quality and redundant EAs especially in large enterprises and requires corresponding governance concepts. Hence, this approach mainly applies to standalone EAs without complex integration and computing needs. The business-process-driven-approach ensures integration with business processes and back-end systems but requires a much more complex and time-consuming development process.

3.2. Enterprise App IT Architecture

The use of EAs poses new requirements on the enterprise IT architecture. Especially back-end-integrated EAs need unified and easy access to various functions and data sources of heterogeneous enterprise IT systems. Existing enterprise IT landscapes are typically based on the service-oriented architecture (SOA) [15] paradigm integrating heterogeneous IT systems as loosely coupled unified services, mostly based on web service technology.

However, existing service definitions typically represent complex multi-function business services, such as maintaining a machine. Thus, they have to be decomposed in multiple single-function services, e. g., machine failure documentation, to make them app-compatible. Consequently, an additional abstraction layer with novel services results as part of the SOA comprising so called mobile friendly services [4]. These services have to follow the single-function paradigm and need to be tailored towards the limited memory and computing power

as well as transmission bandwidths of mobile devices. Moreover, they are likely to have shorter software life cycles because updates of single functions can be developed and deployed more quickly. This in turn requires an agile SOA governance to enable a quick definition and provisioning of new mobile services and, thus, corresponding new EAs.

3.3. Enterprise App Development

EAs have to be developed for multiple mobile platforms, e. g., Apple iOS and Google Android, across multiple devices, e. g., smartphones and tablet PCs. In general, three types of apps can be distinguished, namely web apps, native apps and hybrid apps [4].

Web apps are platform independent and run in an arbitrary web browser. This leads to high flexibility, but special hardware functions, such as graphic accelerators, are not available and user interfaces (UI) are usually not optimally adapted to the specific mobile device.

Native apps are developed for a single platform, thus hardware like camera or GPS can be used and the UI can be adapted to the look-and-feel of the platform. The disadvantage of native apps is the high effort for porting them to other platforms. This effort is often underestimated, because with changing the platform, hardware functionality, UI look-and-feel and programming language also change, which leads to an almost new app.

Hybrid apps try to overcome the disadvantages of web and native app development. Thus, the app is developed in a platform independent programming language and subsequently translated into the target platform. This leads to a higher effort when developing an app for a single device, but hybrid apps have an advantage when the app is brought to multiple platforms, where the overall effort is reduced compared to native apps. Additionally, hybrid apps support some special hardware functions and thus can provide more functionality like web apps.

In this article, we focus on hybrid apps because they combine the advantages of web apps and native apps. To enable an effective and efficient hybrid app development, so called mobile enterprise application platforms (MEAP) [16], e. g., the Sybase Unwired Platform [17], are employed. A MEAP is a middleware supporting the development of apps across multiple platforms and devices. Moreover, it provides middleware services, e. g., for secure communication, data access and authentication.

To ease development of hybrid EAs in manufacturing companies and enable a user-driven development approach as described in Section 3.1, we propose the concept of a manufacturing-specific extended MEAP. It represents not only a technical but a semantic middleware for manufacturing-specific EAs. That is, it supports the definition of mobile friendly SOA services and is based on a common manufacturing data model which all services refer to. Moreover, it integrates enhanced data security functions as described in Section 3.5 in a transparent manner and provides standardized UI components and style elements according to corporate design guidelines. Hence, developers can focus on the programming of the actual business logic and expert-users can develop their own EAs in a user-driven approach.

3.4. Enterprise App Infrastructure

Building an EA infrastructure needs to address an enterprise app store and an efficient mobile device management in order to deploy and manage EAs across multiple platforms and multiple devices.

The app store plays a central role in a mobile enterprise strategy. All apps are provided by the app store and thus the reliability with respect to security and privacy is of great importance. A strict inspection process has to be established to guarantee that no vulnerable apps can get into the app store. The app store controls the access to EAs, thus, employees can only see and install apps they are authorized to use.

The app store has to support deploying EAs in a unified way on mobile devices. Yet, the arrangements made by public app stores, e. g., Google Play and the Apple App Store, are not sufficient. A specific enterprise app store has to fulfill the following requirements: EAs published in the app store need to be quality-assured and trustworthy. Thus, the developer's identity has to be known and a system of certification and quality tests has to be defined. Moreover, a cross-platform provisioning for different mobile platforms is required. Unfortunately, Apple devices can only be provisioned by Apple's App Store limiting cross-platform and company-internal app store concepts.

3.5. Enterprise App Security & Privacy

Security and privacy play an important role for EAs and mobile devices due to high vulnerability to security attacks. Three major areas relevant for EA security can be identified:

- Back-end integration
- Mobile device
- Communication channel

Authorization and authentication mechanism to access enterprise data in the back-end systems are required. Compared to current solutions with virtual private network (VPN) connections, various passwords and certificates, which are often very cumbersome, simple and user friendly mechanisms have to be developed and integrated into corresponding MEAP concepts.

Mobile devices and their operating systems need several precautions to ensure confidentiality and trust of EAs and corresponding data apart from typical anti malware software. In case of stolen or lost devices, all data should be encrypted in general. Moreover, functionalities to remotely wipe, lock or clear passcode of a device are required. Existing approaches are solely software-based. We envision additional hardware-based approaches based on trusted computing concepts, which ensure trustworthy operation of security-relevant components, e. g., encryption processes [18].

Additional precautions are particularly important for mixed private-business usage scenarios: Using private smartphone and tablet PCs for business tasks gets more and more common and enterprises allow employees to 'bring-your-own-device' (BYOD). Thus, mobile devices are not completely under control of an IT department and private apps and corresponding data have to be separated from business-related items. Software virtualization is a first promising approach to ensure isolation and trust of enterprise-related content on private mobile devices [19].

All mobile devices communicate with other devices over wireless connections such as Wi-Fi and UMTS. These communication channels have to be encrypted to prevent theft of data during data transmission or deployment of apps over the air. Corresponding protocols like Transport Layer Security (TLS) are well established but have to be consequently used for all communication activities, e. g., with back-end systems, app stores or other mobile devices.

Considering privacy issues, mobile devices introduce new problems such as tracking or generating detailed profiles of employees. This is especially relevant for countries like Germany with strict regulations for employee privacy. Novel solutions are necessary to make use of context data and ensure privacy at the same time. For example, algorithms like k-anonymity [20] have to be adapted to the context of mobile devices usage.

4. Enterprise Apps Across the Product Life Cycle

In the following, we structure existing EAs for manufacturing companies across the product life cycle [21] and present exemplary EAs (see Fig. 2). Thereby, we focus on back-end-integrated EAs running at least on one of the following three mobile platforms, namely Apple iOS, Google Android and Microsoft Windows Phone. In addition, we point out new use cases and fields of applications for novel EAs.

Many existing EAs for manufacturing companies focus on sales and distribution as well as service and support to integrate mobile employees in business processes. Classical enterprise software vendors like SAP and Oracle therefore transfer selected functions of their ERP and CRM systems to mobile devices. E. g., the Oracle Mobile Sales Assistant app [22] provides mobile access to customer contact data, leads, orders and product information. Moreover, there are EAs for field technicians, such as the Bizerba Technician app [23] supporting time recording, case handling, viewing of technical product documentation and spare part procurement.

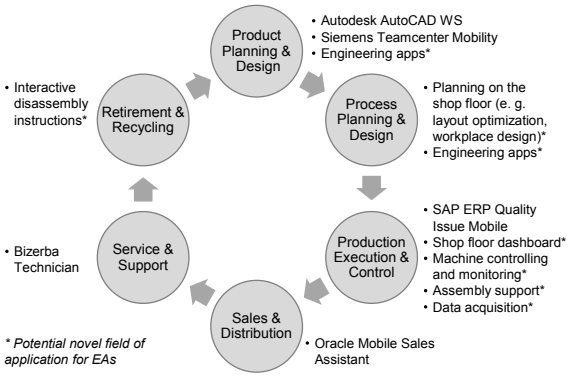

Fig. 2. Enterprise apps across the product life cycle

Apart from generic EAs for project management and PIM, there is only a little number of specific EAs for the core activities of manufacturing companies, that is, planning and design of products and processes as well as production execution and control. Regarding product planning and design, computer aided design (CAD) systems are augmented by apps, e. g., the Autodesk AutoCAD WS app [24], enabling the rudimentary mobile viewing and editing of CAD drawings. Similarly, apps for product data management, e. g., Siemens Teamcenter Mobility [25], support the browsing of product information and models as well as change and version management.

Regarding process planning and design, we could envision EAs that enable the design of processes based on virtual reality (VR) concepts. E. g., while walking through the factory, layout changes in a VR model could be made while inspecting the physical circumstances on the shop floor. Moreover, Westkämper proposes a huge variety of novel standalone EAs for engineers, so called engineering apps, to enhance productivity of daily tasks [11]. Valid engineering knowledge, such as calculation models for thermodynamics and materials engineering, may be converted into corresponding EAs.

With respect to production execution, there are some EAs for quality management, e. g., the SAP ERP Quality Issue Mobile app [26], to create and track quality issues on the shop floor. In addition, we see a huge potential for novel EAs for workers on the shop floor, ranging from apps for monitoring and control of machines over production data acquisition until assembly support.

Production control is in the scope of EAs that extend existing manufacturing execution systems (MES). Initial

apps provide mobile dashboards to support monitoring of production processes based on metrics. Yet, monitoring and analytics results are typically not fed back to the workers on the shop floor. Thus, information provisioning for workers is another field for novel EAs. E. g., the concept of the operational process dashboard for manufacturing [27] provides analytics-driven services, e. g., information on process context and process performance, in order to empower workers.

Retirement and recycling of products have not been substantially addressed by EAs so far. We could imagine novel EAs, e. g., to support disassembly of products by interactive disassembly instructions.

5. Summary and Conclusion

In this article, we presented a conceptual framework for EAs with five essential components, namely EA portfolio, EA IT architecture, EA development, EA infrastructure and EA security and privacy. We are currently applying the framework in case studies at manufacturing companies to validate and refine it. In this context, we observe strong interest in EAs for mobile Business Intelligence, especially for the dashboard-based monitoring of manufacturing processes using key performance indicators. Moreover, EAs for mobile approval tasks, e. g., in product development, are said to significantly speed up processes. Major obstacles are, on the one hand, the advancement of legacy IT systems in order to expose their functions to EAs and, on the other hand, data security concerns with respect to lost and stolen devices. Cross-platform issues are partly avoided by enterprise-wide platform standards for company-owned devices.

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