Assistance- and Knowledge-Services for Smart Production

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ABSTRACT

The transformation towards Smart Manufacturing results in machines that are increasingly complex to use and to maintain, as well as in ever-complicated production processes. Coupled with a continuing reduction of staff, this leads to an increasing demand for information needs and work expertise. At the same time, these challenges offer the opportunity to enhance the employee's leeway with respect to designing and organizing their work. The project APPsist focuses on how this transformation can be supported technically and organizationally. This paper presents the technical approach: an architecture for intelligent-adaptive assistance and knowledge services. The paper describes how process mapping identified the requirements of the APPsist system, and presents the identified services and their communication, as well as the intelligent-adaptive functionality of the services.

CCS Concepts

•**Applied computing** → **Computer-assisted instruction;**

Keywords

Workplace learning, assistance services, adaptivity, smart production

1. INTRODUCTION

Today, Europe's manufacturing companies face the challenge of how to increase their competitiveness in a time where measures such as moving to low-cost production sites, raising process quality, or improving machines have been almost fully exploited. Furthermore, individualization of production increases, resulting in an ever increasing number of product variants and at the same time smaller batch sizes. One solution to these challenges lies in the flexible automation of production facilities [9]. The term "Smart Manufacturing" describes processes that integrate embedded systems, production, logistics, engineering, coordination and management processes as well as Internet services. One widely established approach in Smart Manufacturing is based on Cyber-Physical Production Systems (CPPS) that integrate software as well as physical components [15].

Despite the increasing automation, human operators will have their place on the shopfloor albeit with a changed role. Thus, technological innovation cannot be considered in isolation, but requires an integrated approach drawing from technical, organizational and human aspects, forming a socio-technical system [7]. The flexibility made possible by CPPS further increases complexity with regard to usage and maintenance of production lines as well as the control of the production process. For the human operator, mastering this complexity requires larger amounts of knowledge and deeper job expertise than ever before. Information providing and training processes therefore have to become more flexible, integrated in the workplace, and individualized. This article gives an overview on the APPsist project, which aims at developing a new generation of mobile, context-sensitive and intelligent-adaptive assistance systems for knowledge and action support for Smart Production.

2. RELATED WORK

Existing work in the area of learning at the workplace uses physical devices to interact in virtual worlds (the mixed reality approach) [8], or, mainly in the area of software applications, performance-support-systems [3]. Support systems that target Smart Manufacturing are already applied in manufacturing, focusing on very specific areas, mostly assembly, e.g. in order improve control [2] or monitoring [16].

Another line of research investigates the use of Web 2.0

i-KNOW '15, October 21 - 23, 2015, Graz, Austria

ISBN 978-1-4503-3721-2/15/10…$15.00

DOI: http://dx.doi.org/10.1145/2809563.2809574

technologies for imparting knowledge in a variety of settings, such as creation and exchange of content for maintenance [13] and support of car mechanics for maintenance and repair [5]. Automatically derived information about the context has been shown to be useful for configuring social networks used in company-wide knowledge management [1] and for the transfer of practical knowledge in repair workshops [4]. The EU project “Learning Layers” investigates informal learning at the workplace. Among other, an infrastructure is being developed that brings semantics to social networks to improve interaction with content and services [10]. As it is still work in progress, a comparison to the APPsist approach is difficult at this point in time.

Systems that use methods of Artificial Intelligence to adapt themselves to the individual learners (Intelligent Tutoring Systems, ITS) offer the most advanced support of learning. However, existing work in this area mainly focuses on school and university education. APPsist is one of the first systems that applies the ITS paradigm to workplace integrated learning on the shopfloor. A related project is DigiLernPro [6] which focuses on the semi-automated generation of learning scenarios that support workers in performing various tasks while working with production machines.

3. THE APPSIST PROJECT

The goal of the APPsist project is to develop a new generation of mobile, context-sensitive and intelligent-adaptive assistance systems for knowledge and action support for Smart Production. The project focuses on the skills and competencies of the staff and attempts to compensate for any skills that may be lacking with respect to performing tasks at the workplace (action support). In addition, knowledge-support services facilitate the continuous expansion of staff expertise through the acquisition of knowledge and skills in relation to production, product, and process. The aim is to promote the professional development of the staff so that they can gradually start to perform more demanding tasks and serve as a counterbalance to the demographic change and the shortage of skilled workers. This support includes the setup and operation of a manufacturing unit in the production process, as well as the preventive maintenance, maintenance, and troubleshooting.

The requirements of manufacturing companies, represented in the consortium by three companies, guide the research activities and development in APPsist. The three companies range from small- over medium- to large-sized. In order to cope with the complexity of the domain, the consortium identified three pilot scenarios, one in each company: The *small-sized company* produces complex customer-specific tools and devices for car manufacturers and their suppliers. The pilot scenario focuses on installation and use of devices (milling machines). The *medium-sized company* produces customer-specific welding and assembly lines for car manufacturers. The pilot scenario focuses on error diagnosis and correction in the customer-specific machines. The *large-sized company* produces pneumatic and electric controllers for the automation of assembly-lines, which are used in customer-specific products as well as in their own production. The pilot scenario focuses on maintenance and repair, in particular outages (replacement of adhesives).

4. PROCESS MODEL

The assistance and supply of adequate information requires a description of the tasks (or processes) of employees that fulfills the following requirements: The processes have to be easily and uniquely understandable with respect to their content and structure, and there cannot be any room for interpretation (clearness & transparency); the defined processes must always lead to the same goal (reproducibility); all possible tasks have to be defined within the processes (completeness). To ensure these quality requirements, we defined a process model that provides guidance for defining process descriptions. First, process designers as well as company-specific experts (e.g. workers on shopfloor level and production managers) work together to describe the processes as they are currently used in the company (actual processes), using the BPMN-notation (see Section 5.1). Those defined processes represent a usable but not necessarily optimized and complete method. Thus, in a second step the experts optimize the structure and content of the captured processes.Then, the following information is added to each process step: required *devices* (tablets, smart-phones, smart-glasses, smart-watches etc.); required *media contents* (texts describing each of the process steps, videos, photos, models, augmented reality, warning messages); required *data* from IT-systems (e.g. PLC, MES, ERP), which trigger a procedure (e.g. fault messages) or which influence the assistance (e.g. data of a door sensor); and required *interaction* of the user (e.g. input at an operating panel of a machine).

5. SOFTWARE ARCHITECTURE

The diverse usage scenarios demand a large amount of features to be provided by the assistance and knowledge building platform developed in the APPsist project. The challenge is to combine these features in an integrated and consistent system. As a first step to approach this goal, we decided on a service-oriented architecture: each feature is realized by a dedicated and as far as possible independent service with a well-defined interface for the other service to access the feature. The services are then composed to a single platform. We followed the principles of a microservices architecture [11]: The services are fine-grained, replaceable and self-contained and the features are provided by lightweight application interfaces. This allows us to develop and maintain them independently and gives us great flexibility in regard to the technology we use to realize the single services. At the current state, the APPsist platform contains half a dozen core services and several system services. An overview of the architecture is shown in Figure 1. The core services are:

- *Site Information Service*: an interface between the machine data provided by the sites' SPS controllers and MES system on the one side and the APPsist platform on the other.
- *Measure Service*: recommends measures to be performed by the operator based on site and user contexts.
- *Process Coordination Instance*: executes processes and manages their execution contexts.
- *Performance Support Service*: guides the user through the assistance process.

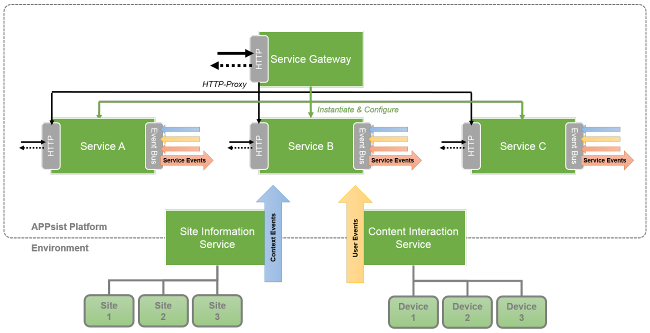

Figure 1: Service-oriented architecture of the APPsist platform.

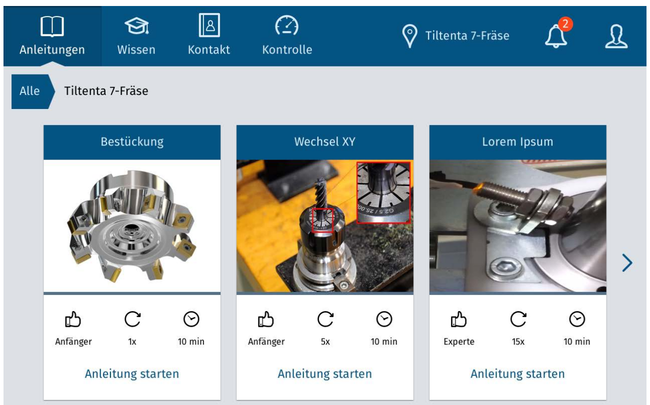

Figure 2: A visual design illustrating the main menu of APPsist.

- *Content Selector*: selects the optimal content for both assistance and knowledge building processes.
- *Content Interaction Service*: provides the user frontend and makes the features of the services available on the terminal device. Figure 2 gives an example of the frontend.

The system services provides necessary platform features such as data and content management, user management, session management, authentication and authorization. It is possible to use only a subset of the services to compose a platform for a specific domain, i.e. a platform instance.

Beside the service-orientation, the system architecture follows an event driven approach. There are several areas where events originate: events can be created based on user interactions, context changes (e.g., a state change of a connected machine), or be generated by the services themselves. The latter event type occurs when a service processes incoming events and generates, often based on a rule set, a higher level event to be distributed to other services. In general, events are broadcasted to the whole system, so the services can decide independently if they either consume an event or drop it. The events are both syntactically and semantically specified and part of the APPsist ontology (cf. Section 5.1).

To realize consistency for the service interfaces and configuration, we use the Vert.x middleware [18]. Each service is represented as module within the Vert.x runtime. The modules communicate with each other using two mechanisms: request-response calls are realized using the HTTP protocol, whereas a publish-subscribe mechanism allows a distribution of messages such as platform events. Vert.x provides both a high-level API to create performant HTTP servers and clients and a distributed event bus to exchange data objects between modules. The data exchanged is mainly encoded in JavaScript Object Notation (JSON). The modules can be implemented in any language running on the Java Virtual Machine.This allows a developer to choose the language which fits most to the features the service should provide.

The final composition of a platform instance is stored in a configuration file. This file is consumed by a special system service, the *Service Gateway*. This services has two primary features: on the one hand, it deploys and instantiates the services from a repository based on the information provided by the platform configuration. On the other hand, it provides a proxy which routes requests to the individual webservers of the services and acts therefore as central and uniform access point for all HTTP requests.

Based on first experiences, the microservices architecture a has proven itself as a good approach for the creation of a flexible system build by mostly independent development teams in the context of an evolving research project. The Vert.x middleware enables us to maintain an integrated platform through the constant process of change.

5.1 Knowledge Representation and Intelligent Services

APPsist contains a model of the shopfloor domain (the APPsist ontology), i.e., the domain concepts and entities and their relationships are modeled in a formal description language (OWL [17]) and stored in a semantic database (a triplestore). This model defines an unambiguous vocabulary used for communication between the services and serves as the basis for the reasoning processes of the adaptive services. For instance, the measure service determines the measures applicable in the current situation through a semantic database query (SPARQL [14]). SPARQL offers a relatively easy to master yet expressive query language, based on a standard and thus is reusable. The semantic model also allows adding new or changing concepts and refinements without having to change other parts of the model or the queries. It is still an open question whether OWL and SPARQL offer sufficient expressiveness to cover the needs of the intelligent services. Also, there was no need yet to use the advanced functionality offered by the semantic database (automatic deduction of new facts from the available information).

The process model is specified in BPMN (Business Process Model and Notation [12]). BPMN includes the graphical layout as well as the semantic representation, and allows the execution of the processes (in APPsist in the process coordination instance), as the semantic of process elements are uniquely specified. For APPsist, a subset of the extensive specification is sufficient to model the measures. These are Start and End Events, Tasks, Sequence Flows and Exclusive Gateways, as well as Call Activities. The functional integration of the process models in APPsist requires to add different kind of data. This includes: data for creating events and call activities; triggers that are used during process execution; events that are created at the start or end of a process execution; and calls of APPsist services through their interfaces. This was realized through a BPMN-conform extension in the process definitions.

6. CONCLUSION

This article gave an overview on the current state of the APPsist project. The approach based on pilot scenarios to determine the requirements of assistance systems in smart manufacturing in sizeable yet comprehensive sub-domains proved very helpful. However, it is now necessary to widen the perspective in order to include activities that require higher levels of skill. The developed process model will prove helpful to ease capturing new scenarios.

Today's technologies serve as a good basis to implement flexibly configurable systems. Service-oriented frameworks allow the independent development and the integration of a system from separated sub-systems. Standards of the Semantic Web enable precisely defined communication between services as well as the realization of intelligent services. The further development will show to what extent the transfer to new domains is eased by the APPsist approach. We expect that the overall architecture will stay intact, albeit with small modifications of the services and data structures.

The article could not cover all aspects of the APPsist project. Significant effort focuses on organizational issues that concern the system implementation in the sense of establishing it within an existing shopfloor. This includes the draft of shop agreements between employer and works council, taking into account the right of co-determination (workers' representation) and legal aspects (privacy, warranty).

7. ACKNOWLEGDMENTS

This publication is a result of work performed in the context of the project "APPsist – Intelligente Wissensdienste für die Smart Production", funded by the German Federal Ministry for Economic Affairs and Energy (BMWi), number 01MA13004C and supervised by the DLR. The authors are solely responsible for its content.

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