The Mobile Manufacturing Dashboard

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***Abstract*—Real-time monitoring and analysis of manufacturing processes are critical success factors for the smart factory. While there is a variety of data analytics tools for process optimization, almost each of these applications is designed for desktop PCs and focuses on selected process aspects, only. I. e., there is a gap between the site the analysis outcomes occur (*the management level*) and the site where an immediate reaction to these results is required (*the factory shop floor*). Even worse, there is no mobile, holistic and analytics-based information provisioning tool for workers and production supervisors on the shop floor but rudimentary systems designed for limited application areas, only.**

Therefore, we introduce our *Mobile Manufacturing Dashboard* (*MMD*), a situation-aware manufacturing dashboard for mobile devices, as a key enabler for the *Industry 4.0*. The MMD provides advanced analytics and addresses the full range of process-oriented information needs of both shop floor workers and production supervisors. In this paper, we give a brief overview of the MMD's major architecture and implementation aspects and describe two representative real-world scenarios for the MMD. These characteristic scenarios provide the basis for our demonstration at the PerCom Demo Session.

***Index Terms*—Mobile application; smart factory; data analytics; process optimization; Industry 4.0.**

I. Introduction

Comprehensive mobile information provisioning plays a key role to facilitate flexibility and efficiency of operations in the smart factory [1]. Workers and production supervisors have to monitor the process state and its performance in real-time to react on incidents and communicate solutions immediately [2]. For instance, if an input material in combination with a certain machine set-up in a manufacturing step usually leads to performance problems in subsequent steps, real-time prediction capabilities should warn workers during process execution and provide precise action recommendations on how to avoid the problem. This requires information about the *current state of the entire process* and its *performance* regarding metrics such as duration or quality. Additionally, information about work instructions and improvement suggestions, that is, *process knowledge*, as well as *process communication* has to be available. Besides, all this information has to be provided in a *situation-aware* manner to make adequate use of it anytime and anywhere on the factory shop floor.

Existing mobile applications lack in three key points: (1) they do not fully address all process-oriented information needs of employees on the factory shop floor; (2) they do hardly exploit context data to provide situation-aware information, e. g., considering the role and location of the user as well as current process events; (3) they do not employ advanced analytics, especially data mining, to enable predictive optimization.

To address these aspects, we present the *Mobile Manufacturing Dashboard* (*MMD*), a situation-aware manufacturing dashboard for mobile devices. The MMD provides advanced analytics and addresses the full range of process-oriented information needs of both shop floor workers and production supervisors. Therefore, we give an overview of related work in Section II and present the MMD as well as its underlying architecture in Section III. Next, Section IV comprises details about the implementation of the MMD before Section V closes with an explicit description of our demonstration's contents and requirements.

II. Related Work

We did a comprehensive analysis of mobile applications for monitoring and controlling of manufacturing processes in our previous work [3] comprising both industry applications and research prototypes: Applications such as OpsTrakker[1] or SAP Quality Issue Mobile[2] extend manufacturing execution systems and enterprise resource planning systems. They mainly focus on scheduling and metrics management for production supervisors as well as data acquisition for workers. The prototype in [2] goes beyond that and offers real-time visualization of process performance information for workers in logistics. However, these existing applications do not provide a holistic view on all process aspects and are limited by the three shortcomings outlined in Section I.

III. The Mobile Manufacturing Dashboard

In our previous work [3], we evaluated process-oriented information needs in manufacturing and defined requirements for a situation-aware and analytics-based manufacturing dashboard. This constitutes the basis for the technical architecture of the MMD shown in Figure 1. It comprises three integrated layers and makes use of our Advanced Manufacturing Analytics framework [4].

The *Data Integration Layer* comprises the *Manufacturing Knowledge Repository*. It integrates structured and unstructured manufacturing data, e. g., process execution data, machine manuals and failures reports, in order to provide a holistic view on all process aspects. To this end, the knowledge repository combines features of a process warehouse and a content store

[1]http://goo.gl/c8W8pY
[2]http://goo.gl/0thkjc

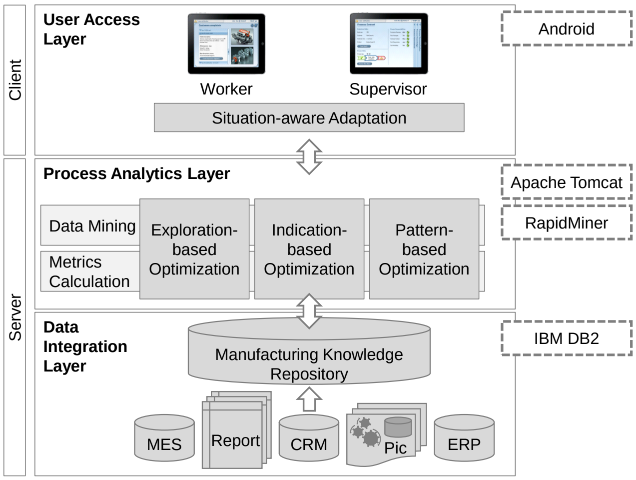

Figure 1. Architecture of the Mobile Manufacturing Dashboard

and facilitates the sharing of analysis results such as data mining models.

The *Process Analytics Layer* provides three groups of optimization services, which make use of various analytics techniques, especially data mining and metrics calculation. *Exploration-based Optimization* refers to the browsing and exploration of analysis results in the knowledge repository, e. g., to view metrics of a certain machine. *Indication-based Optimization* presents indications for process improvement using data mining-based predictions and root cause analysis concepts. *Pattern-based Optimization* goes beyond that by using data mining techniques to generate action recommendations during process execution to avoid a predicted metric deviation.

The *User Access Layer* enables the mobile and situation-aware usage of these optimization services on the factory shop floor for both workers and production supervisors. For the situation-aware parametrization, it combines information on the current process context, i. e., process events as represented in the repository, the user context, i. e., the user's role, and the mobile device context, e. g., using its microphone for noise level detection.

Due to several legal rules and regulations, a system such as the MMD has to ensure data security as well as user privacy, as it not only processes sensible company data (e. g., process performance or financial outcomes) but is also able to draw inferences from the mobile devices' information about the user behavior (e. g., working hours, work pace, etc.). To ensure data security, a role-based view on the data is realized in the repository. Each user has access to a limited dataset, only. In this way, it is guaranteed that, e. g., production supervisors do not profile individual employees. Moreover, all data is securely located in the server-side repository without storing it on the mobile device. For the sake of simplicity, we disregard privacy issues in our prototypical implementation of the MMD at the moment. However, there are approaches for privacy-preserving data mining (e. g., [5]) which could be applied on our server-sided data processing. Besides, privacy management systems for mobile platforms (e. g., [6]) can be exploited for the MMD's client application if it is deployed in a real-world scenario.

From a user's point of view, the MMD provides situation-aware services on the four major areas of process-oriented information as described in [3], namely process state, process performance, process knowledge and process communication, for workers and production supervisors in a role-based approach. The *process state* refers to an overview of the current state of the entire process and all underlying resources, e. g., current work orders or failures. *Process performance* not only focuses on metrics but provides real-time prediction and root cause analysis as typical indication-based optimization services. E. g., the total duration of a process instance may be predicted. Moreover, as part of pattern-based optimization, workers proactively receive recommendations on how to avoid a predicted metric deviation for the currently running process instance, e. g., to speed up processing by using a special machining tool. *Process knowledge* is provided on the one hand by process documentation, e. g., machine manuals and help documents for a process step. On the other hand, there is a knowledge management component to generate problem tickets and improvement suggestions for process improvement. E. g., a worker may take a photo of a broken machine and post it to all other workers and supervisors, who may rate and extend the suggestion by a corresponding solution proposal. Finally, *process communications* focuses on an asynchronous message exchange, e. g., to react to turbulent situations using text messages. The situation-aware use of these services is described in Section V.

IV. Implementation Details

Our implementation is based on a client-server architecture, with the server-side back-end comprising the data integration layer and the process analytics layer (see Figure 1). The client, that is, the user access layer, is realized as a mobile application for Android-based mobile devices. The Manufacturing Knowledge Repository is implemented on the basis of IBM DB2 Infosphere Warehouse using its XML and large object processing facilities to handle unstructured data. The process analytics components are implemented in Java EE and use RapidMiner for data mining. The client-server communication is realized via HTTP requests. For the indoor localization of smart devices, there are various strategies, e. g., [7], [8]. Yet, they require additional efforts to apply them on the factory shop floor or they are not applicable at all in such an environment, e. g., due to electromagnetic interference. Therefore, we use a tag-based concept in our prototype of the MMD. The current location of a user is determined via QR codes, which are attached to work places and machines and link logical factory constructs in the knowledge repository with physical locations.

V. Demonstration Setup and Requirements

Our demonstration comprises two representative real-world scenarios of the MMD, one focusing on a worker and the other focusing on a production supervisor. These scenarios are

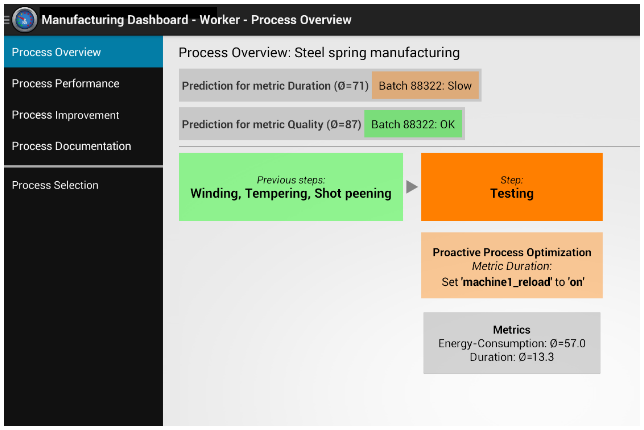

Figure 2. MMD of a worker: Performance warning and proactive optimization

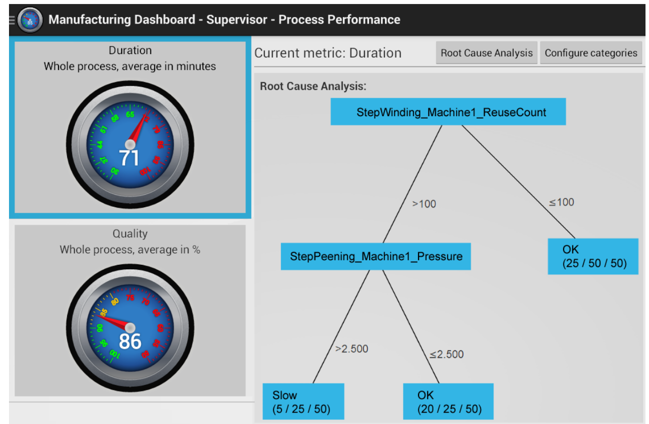

Figure 3. MMD of a supervisor: Root cause analysis of process durations

interrelated and based on a manufacturing process for the batch-oriented production of steel springs for cars as described in [9]. They illustrate the situation-aware provisioning of analytics-based information in the smart factory combining process context, user context and mobile device context.

In the following, we detail on the two scenarios which are presented in our hands-on demo for all conference attendees. We make the server-side back-end available via a laptop and provide two Android tablet PCs with WiFi connections as clients. Machines are represented by QR code printouts. Additionally, only one table and a power source are needed.

A. Application Scenario for a Worker

Step 1: The worker logs in at the MMD and scans the QR code of the machine s/he works at. Thereby, the worker is registered for the respective manufacturing process and the state of his or her process step and the related machines is shown. Initially, there are no warnings or failures and the worker begins with the processing of the first batch of steel springs.

Step 2: The worker receives a real-time-prediction-based warning from the MMD that the process duration of the next batch is likely to exceed the defined maximum duration at the end of the process. Thus, s/he is automatically presented a proactive recommendation on how to avoid the predicted duration overrun and is advised to adjust some machine setting to speed up processing (see Figure 2). Both the prediction and the recommendation are dynamically generated using process data in the knowledge repository for decision tree induction.

Step 3: The worker does not know how to reconfigure the machine and therefore browses machine manuals and work instructions associated with his or her process step to find information on the machine settings in the process knowledge area. Finally, s/he succeeds in reconfiguring the machine.

Step 4: The MMD alarms the worker that the regular noise level of the machine has been exceeded. Thus, s/he takes a photo of the machine and creates a problem ticket, which is complemented by process data and noise level data. Then, the ticket is stored in the repository and posted to all workers who participate in the process as well as the production supervisor.

Step 5: Another worker recognizes the ticket on his or her MMD and proposes a solution by reducing the oil pressure of the machine. Therefore, s/he responds to the problem ticket in the process knowledge area.

B. Application Scenario for a Production Supervisor

Step 1: The supervisor logs in at the MMD and selects the process s/he wants to monitor. Then, s/he is presented an overview with the current state of the entire process and s/he investigates current failures and problem tickets of all process steps. S/he notices the problem ticket about the machine noise and marks it as solved in order to prepare it for further reuse in process instructions.

Step 2: Due to excessive process durations, the supervisor executes a root cause analysis. For this purpose, s/he configures the critical duration categories and generates the decision tree labeled with the categories (see Figure 3). This reveals that the use of a certain machine seems to be a major influence factor.

Step 3: For an on-site inspection, the supervisor walks through the factory to the respective machine, scans the QR code and analyzes metrics and manuals associated with the machine. Finally, s/he orders an additional inspection to exchange heavily worn machine parts.

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