Saving Energy in Production Using Mobile Services

Christopher Ruff, Uwe Laufs, Moritz Müller, Jan Zibuschka

Fraunhofer-Institut für Arbeitswirtschaft und Organisation IAO
Nobelstraße 12
70569 Stuttgart
Christopher.Ruff@iao.fraunhofer.de
Uwe.Laufs@iao.fraunhofer.de
Moritz-Christian.Mueller@iao.fraunhofer.de
Jan.Zibuschka@iao.fraunhofer.de

Abstract: High energy costs have led to an increasing relevance of energy-efficiency over the last few years. While new equipment is mostly designed to be energy-efficient, feasible action is needed to decrease energy consumption of existing equipment on the shop-floor level. As interventions there rely on dependable information and its use at the right time and place, involvement of ICT systems and particularly mobile devices becomes evident. In our approach, a system based on a SOA back end and a mobile device-based front end was implemented as a prototype. The system uses data provided by sensors, production orders and additional metadata describing specific properties of the production systems to provide decision support and to generate recommendations for the stakeholders to realize immediate as well as longer-term energy savings.

Keywords: Energy-efficiency, Production, Architecture, Mobile Assistance

1. Introduction

Sustainable production and energy-efficient production are generally seen as the central new paradigms [JKB03] for production research within the next years. More specifically, energy-efficiency has become a more and more important aspect of sustainability, which was originally coined to describe systems allowing for an agile response to competitive challenges [JKB03].

IT Systems can contribute to realizing energy savings in several central ways: they are both needed to analyze energy inputs, which can hardly be performed manually in today's complex manufacturing processes, and to control the production machines on a fine-granular level to realize energy savings based on the analysis of the inputs [BV10].

Usage of smart mobile devices is rapidly becoming more and more prevalent in the workplace [Fo12]. While offering various means of communication, the computational power, visualization capabilities and input methods also make these devices a viable platform for the development of sophisticated business applications. Mobile assistance systems and applications have proven helpful in various industry fields [Um09, Le07], but there have been no serious attempts to leverage their abilities in a context of improving energy efficiency in a production environment. A major challenge regarding the realization of such a system is heterogeneity, including different kinds of sensors, a wide range of components within the production systems, and third party systems such as ERP systems.

2. Requirements

There are several technical requirements that have to be addressed by the system's architecture, which were derived from a prior analysis of literature and application scenarios [LSZ11]:

Requirement I: Regarding the heterogeneous environment, that includes sensors, ERP systems and several other internal system components, the system's architecture to be able to deal with heterogeneity and interoperability aspects.

Requirement II: Because of the wide range of application areas in which the system may be used, it has to be extensible and able to integrate into other external environments with minor efforts.

Requirement III: For the hardware of the mobile assistants, several requirements have been identified: In order to realize a mobile solution, a relatively small form factor is needed, enabling the users of the assistant devices to carry the devices without much effort and without interfering with their main objectives. Specifically:

- Wireless technology is required to connect them to the SME's intranet and efficiently communicate with the services of the system's back-end.
- A high resolution display allowing the creation of an intuitive, easy to use user interface using high level widgets as well as graphs to visualize data such as the current status of the assembly components is necessary to efficiently convey complex information and data to the user.
- The assistant device should support direct (Multi-) Touch input, as the interaction with the UI (User Interface) and said high level widgets has to be easy, intuitive and barrier free. A touch based approach will allow for a direct interaction without the need to use further input devices.

There is also a set of non-technical requirements which are described in [LZS12]. Related approaches exist aiming at increasing energy-efficiency in production as well as making energy efficient systems more attractive which are also described in detail in [LZS12].

3. Realisation

3.1 Architecture Overview

The system's architecture relies on a service-oriented architecture [Ap12] and common communication standards such as the Web Service Description Language (WSDL) [WS13] and the web service protocol SOAP [SO13] are used for the communication between the services provided on the server side and the frontend on the mobile client. The system also contains a web based configuration front end which is described in detail in [LRZ12]. Regarding persistence, mass data such as frequently captured sensor data is stored in a relational data base system (RDBS) while domain specific information is managed using ontologies (see Figure 1).

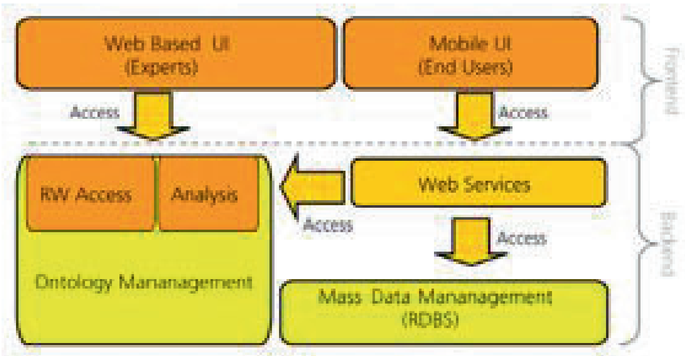

Figure 1: System Architecture Overview

The "intelligence" of the assistance system is realized on the server side as a set of web services. A detailed description regarding the backend part of the system is given in [LSZ11].

3.2 Mobile Front End

To ensure a quick response time to the proposed recommendations by the assistant system at all times and independent of the current user location, a mobile solution is preferable. This allows the system to be utilized directly in the production environment where the recommendations can be implemented directly. This also enables the responsible staff to immediately report back the changes made to the production system to the system's back-end, resulting in more up to date, accurate and reliable data. A prototype application for the mobile assistance system has been implemented and is developed further using continuous integration methods and frequent testing, using model scenarios with different users, production systems and production jobs.

The mobile front-end is realized using the software Framework MT4j [MT12]. MT4j is a java-based open source framework aimed at the creation of visually rich user interfaces which can be interacted with using novel input methods and devices, having a special focus on multi-touch and gesture support. MT4j relies on the OpenGL API [Op12] and its mobile counterpart OpenGL ES [Op13] for rendering graphics. First developed for the desktop, it has since been ported to Google's Android platform, expanding its use onto various mobile devices. It facilitates development of graphical user interfaces by providing high-level widgets and easy to customize components while also providing ways for intuitive and customized interaction. The developer has the ability to attach individual input processors to every component, allowing for processing of input data and the recognition of the users intent. Several, input processors can be attached to a visible component simultaneously, each parsing the input data for a defined pattern. If the criteria for e.g. a flick-gesture are met, the input processor responsible for processing and recognition of that input pattern dispatches gesture events on to the presentation layer. There, gesture event listeners can be defined allowing for a custom action to be taken in case of receiving such events. The MT4j framework comes with a set of pre-defined input processors and gesture listeners covering many established (multi-) touch based interactions such as tapping, flicking, pinching or rotating. In order to cleanly separate different functionality and aspects of an application, MT4j provides a concept of having different scenes. A scene represents all the widgets, components and the corresponding input processing of a screen in an application. In our prototype, we make heavy use of this separation to facilitate readability and separation of code with regard to content. The hierarchy of the production system, the login screen or the configuration screen, for example, are each represented by a separate scene. Scenes can be pushed on an internal stack, and subsequently popped, allowing to comfortably navigating to previous scenes by "popping" them from the stack. The "Back"-Button, found on most mobile android devices usually performs this action in our application, conforming to the users' expectations.

When designing the application, several key requirements have been identified and implemented: Visualization of the production environment, Notifications, Energy Efficiency Tachometer.

Visualization of the production environment: The production sites, production systems and assembly components with all relevant data are stored in the back-end model and are fetched from the server using a web service each time the user logs into the application. The information is displayed as a list. Production components which can be navigated through by tapping onto a component to see its sub-components or details of the correspondent component:

Roles: The stakeholders of the system have been grouped into three user roles; decider, planner and machine operator.

Figure 2 View of Components

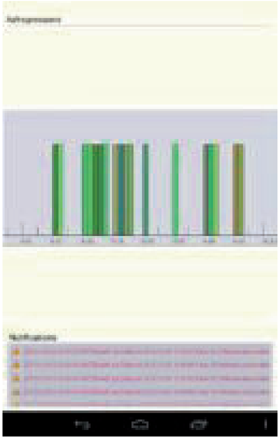

Figure 3 Production Jobs

Figure 4 Notification Details

The application provides different functionality and options for the different stakeholders and their respective roles. We address this by having the user login with their respective username and password at the start of the application. The current user role has an effect on the following aspects of the application:

Roles govern the access and permission to view production sites and production systems retrieved from the back-end model. While deciders have the ability to navigate through the entire production environment, the planners and machine operators are usually restricted to certain production sites and systems. The user role of the decider is offered an additional configuration menu where cost effectiveness of proposed measures can be calculated depending on certain, configurable variables such as aspired amortization dates or production site specific electricity costs.

The machine operator and planner are offered an up-to-date list of orders for production which can also be visualized on a timeline that the user can zoom in or out, using a pinch multi touch gesture (see Figure 3). Notifications are also tailored to the corresponding user role and can only be read if the current user role has the permission to do so.

Notifications: To notify the stakeholders about potential energy saving potential, the frontend regularly queries the backend whether new notifications are available and then transfers them to the front-end by calling the respective front end services on the server. Notifications include information about the measures to be taken in order to capitalize on the energy saving potential (see Figure 4). They conform to our role concept in such a way that every notification can only be read by a specific role or group of roles defined in the back end. The notifications can generally be grouped into two different types: Strategic recommendations and operative recommendations. Strategic recommendations mostly contain information aimed at the role of deciders and planners. The system, for example, shows the availability of alternative, more energy efficient assembly components than the currently used components. Following these recommendations, it is possible to reduce production costs in the long term. Operative recommendations are aimed at the role of machine operators. These notifications are usually more time critical than strategic recommendations and may result in immediate energy efficiency savings. The implemented operative recommendations can contain information to temporarily shut down an assembly component or a whole production system between production jobs. The notifications are prominently displayed in a bar at the bottom of the assistant application so the recommendations are always in direct sight of the user.

Energy efficiency tachometer: As to quickly get a feel for how energy efficient the production is currently operating, a tachometer is displayed beside the production sites, systems or electric assembly components (see Figure 2). The indicator value is calculated by comparing the current operation and configuration of the production system to the optimal and worst configuration calculated in the back-end. The algorithm takes into account possible alternative assembly components as well as how well the recommendations for energy savings are followed.

4. Conclusion

We described a mobile assistance IT System that aims to support SME in order to realize energy savings in production and to thereby increase SME competitiveness by reducing energy costs. The system is designed to provide mobile ad-hoc decision support both in the planning and execution phases of production. The system's functionality employs a combination of data provided by sensors, production jobs and additional metadata describing the properties of the production systems. A service-oriented architecture is used to allow portability of the system across different manufacturing environments. In the next step, the system will be deployed to a real production system and tested in regards to functionality as well as usability and user acceptance.

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