Beyond Context-Awareness: Context Prediction in an Industrial Application

Yong Ding, Hedda R. Schmidtke, Michael Beigl
Karlsruhe Institute of Technology (KIT) TecO, Karlsruhe, Germany
E-mail: {yong.ding, hedda.schmidtke, michael.beigl}@kit.edu

ABSTRACT
In this paper, we discuss the benefits of context prediction for an industrial application in open cast mining. The goal of context prediction is not only to *recognize* the *current* context, but also to *predict* the *future* context. Context prediction enables a system to become truly proactive. For industrial applications, this can entail concrete monetary value. The paper describes the general concept and how it can be applied in production of raw materials, based on currently used technology.

Keywords Context Prediction; Industrial Applications; Context Awareness;

ACM Classification Keywords I.5.0 [Pattern Recognition]: General.

General Terms Design, Economics, Reliability.

INTRODUCTION
Context awareness [1][2] is considered as one of the key issues in Ubiquitous Computing. A particularly interesting domain for applications can be found in heavy industries. In the CoBIs project, for instance, smart container items, the Collaborative Business Items, were able to recognize hazardous situations in chemical storage to ensure workplace safety [3].

In the project SenseCast we go beyond *recognizing* context, and try to *anticipate* critical situations using distributed sensing systems in an industrial setting. Based on context prediction methods [2][4], the SenseCast systems can dynamically optimize system properties and parameters so as to react to a critical situation before it occurs.

SCENARIO
Energy GP have, on the one hand, power plants to generate electricity, on the other hand, they must also consume energy in order to gain raw materials. It would be very interesting for them to know how large their own energy demand exactly is. As we know, the energy supply companies will estimate the energy requirement for their customers (internal and external) for some future time slot, e.g. next month or next year. But this prediction itself is only a lump- sum estimation, which is not adapted to the dynamically changing real-time power consumption.

Open cast mining is the supplier of lignite-fired power plants. RWE AG, the second largest energy supply company in Germany, has three open cast mining sites in the Rhenish coal-mining district [5]. The energy demand of open cast mining for the next day is estimated and reported in the form of a power operation schedule by 8:00 of each day. The amount of energy supplied on the next day is controlled following this schedule.

Currently this day-ahead power demand plan, which depends on the daily mining arrangement among the three mining sites [5], is manually created by the production departments for every hour. This manual input is estimated from the power demand of the specific bucket-wheel excavator. But environmental factors that have a significant impact on the power demand, such as operating mode, location and weather parameters, are currently not considered. Using sensor technology these factors could be determined, or at least estimated, locally, so as to enable spatially fine-grained evaluation and control of power consumption.

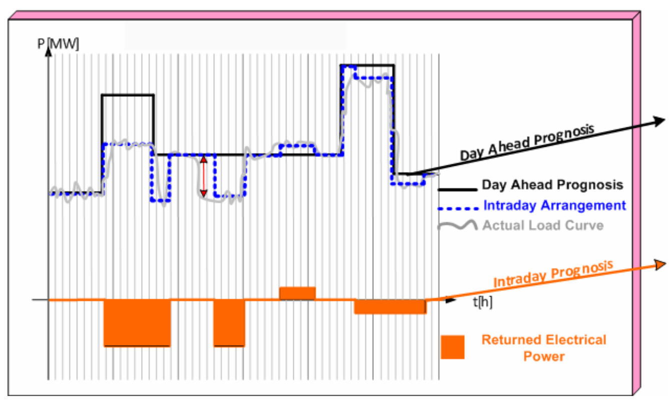

Figure 1. Load curve of intraday and day ahead electrical power

In general the required energy from the previous day is subject to deviations because of the above mentioned aspects, see Figure 1. The power difference between power demand from the previous day (Day Ahead Prognosis) and intraday power consumption (Actual Load Curve) can be identified and evaluated by means of computer-aided operational data sets, such as malfunction period estimation or information about operational modification of devices. Subsequently, the potential variation of power difference (comparison between the solid and dashed lines), which is depicted as Intraday Prognosis in the lower part (orange regions), will be sold by the department of power distribution.

UbiComp'10, September 26–29, 2010, Copenhagen, Denmark.
ACM 978-1-4503-0283-8/10/09.

The above described system is an energy monitoring system that must be observed by personnel all year round for a three shift operation. The actual power development varies continuously over time. If the system observer becomes unavailable for a brief time span, this can already lead to a considerable loss.

For instance, if we consider the duration of the power schedule deviation to be at least 2 hours and the value of the power schedule deviation to be at least 25 MW, a 15mins absence of the system observer would cause a loss of approximate 25 MW * 80 €/MW * 1/4h = 500 €. Wherein the 80€ is the mean value of the basic price of electric power for 1 MW.

SYSTEM OPTIMIZATION

According to the data above, the current manual power estimation causes every day a consumption deviation at least in the order of 50 MWh for a company like RWE. Using a distributed context-aware system with context prediction, we can generate a fine-grained dynamic prediction of power consumption, thus improving the accuracy of approximation, and reducing loss through faster, automated reaction.

Such a system needs several subsystems, namely systems for *sensing*, *computing* (i.e. recognizing) context and for *adapting* to (i.e. predicting and reasoning about) context. Ideally, these processes are realized on a distributed architecture, so as to keep processing of contextual information about open pit facilities local and to form an integrated power optimization system. Currently however, facilities use a centralized architecture for computing day-ahead schedules, which we will reflect in this scenario.

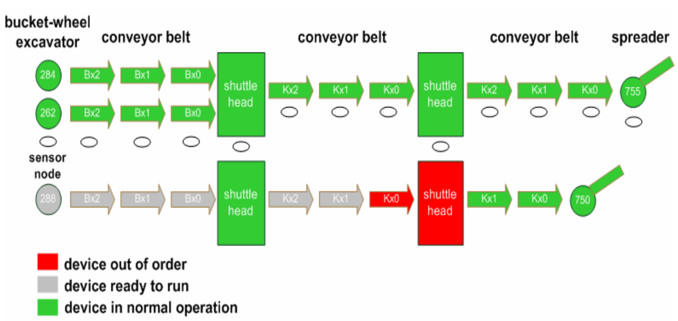

Figure 2. Sketch of open pit facilities and their operational states

Sensing

Contextual aspects, such as weather parameters, location and height can be measured locally with low-cost sensor nodes (see Figure 2) on devices in an open cast mining system. These can tap into local process control systems to also extract other aspects, such as device operating mode, material type and device's nominal power etc. These factors directly and critically affect the energy consumption: The conveyor belt system for example requires more power than nominal power when materials are transported uphill.

Computing

A centralized process control system is currently applied in open cast mining. It uses a client server architecture and consists of a message system, a monitoring system and a Siemens SPC system. Utilizing this central server system, the computing subsystem can be easily realized: (I) all sensor nodes and actuators function simply as input/output devices; (II) context recognition is executed by the central server and managed in the existing signal state database.

Adapting

The conceptual model of the power optimization system considers each sensor node as an input to the context server. Context information is thus accumulated by the server and delivered to its prediction system. Utilizing a time-based context prediction method (e.g. HMM [2]), the prediction system, can activate actuators, so that production facilities are switched off/on by the process control system. Each device can then be optimally adapted to the future situation, and overall power consumption is reduced.

CONCLUSIONS AND FUTURE WORK

We sketched an architecture for context prediction in the industrial setting of power consumption in open cast mining, based on currently used centralized computational facilities. The next step will be to improve on communication overhead and robustness with a decentralized architecture. Context processing, prediction and adaptation can then be realized as collaboration strategies between local sensor nodes.

ACKNOWLEDGEMENT

We would like to acknowledge funding by the German Research Foundation (DFG) in the project "SenseCast: Context Prediction for Optimization of Network Parameters in Wireless Sensor Networks" (BE4319/1).

REFERENCES

1. Anind Kumar Dey. Providing architectural support for building context-aware applications, PhD thesis, Georgia Institute of Technology, November 2000.
2. R. M. Mayrhofer. An architecture for context prediction, Ph.D. dissertation, Johannes Kepeler University of Linz, Austria, October 2004.
3. Decker, C., Riedel, T., Krohn, A., Berchtold, M., Beigl, M., sa de Souza, L., Spiess, P. Collaborative Business Items. *5th International Conference on Pervasive Computing*, Toronto, Canada, In Advances in Pervasive Computing, Late Breaking Results, Austrian Computer Society, ISBN 978-3-85403-219-9, pp 33-36, 2007.
4. Stephan Sigg. Development of a novel context prediction algorithm and analysis of context prediction schemes, Ph.D. dissertation, University of Kassel, Germany, August 2007.
5. Dieter Gärtner. Wettbewerbsfähige Braunkohle durch effizientere Tagebauprozesse. Vortrag Braunkohlentag, RWE Power AG, Mai 2004, Köln.