Using Object Memories For Resource Efficiency

Alexander Kröner
Intelligent User Interfaces
German Research Center for Artificial Intelligence
Saarbrücken, Germany
+49681857755395
Alexander.Kroener@dfki.de

Jochen Schlick
Innovative Factory Systems
German Research Center for Artificial Intelligence
Kaiserslautern, Germany
+496312053703
Jochen.Schlick@dfki.de

ABSTRACT
Object memories support the creation of item-level records, which can be exploited for a deep analysis of processes a physical artefact is involved in. We believe that this technology has particular uses for conserving resources such as energy and water, and thus may provide a valuable contribution to an "Internet for Resource Efficiency". In this article, we discuss this idea on the basis of several application scenarios. We use these to identify research issues related to the application of object memories in this particular field in order to increase awareness of potential benefits and challenges and thus to stimulate research in this area.

Categories and Subject Descriptors
D.3.4 [**Information Systems**]: Systems and Software – *Distributed systems, User profiles and alert services.*

General Terms
Management, Measurement, Economics, Human Factors.

Keywords
Object memory, information collective, resource efficiency.

1. INTRODUCTION
Energy prices in the past seven years have risen by an average of 70%. Over this period, the world crude oil price even increased by more than 350% [1] and became a driving cost factor for the industry of production, transport as well as domestic. However, despite of this threatening development, the per capita energy consumption has been continuously rising during the past years. Therefore, resource efficiency became a key leveler not only to reduce resource depletion and climate change, but also a necessity for industry. This is matched by the consumers' growing ecologic awareness.

In order to ensure a resource-efficient process (or behavior, in the case of the consumer), typically comprehensive knowledge of the involved process steps and actions is required – and their impact on the consumption of resources. Since many processes and actions can be at least in part characterized by involved objects, one way to satisfy this demand for information is to let the object itself contribute to information collection and exploitation. Technically, this can be achieved by linking the object with an IT infrastructure, e.g., by RFID (Radio Frequency Identification).

On the basis of such a link, the Digital Object Memory (DOM) could make processes more resource-efficient. For instance, we showed in [2] how an implementation supporting fine grained information collection and open access along the supply chain could be used to keep track of a product's carbon footprint on item level, to assess it based on information known as typical for this kind of product, and to improve the respective process if needed. This example indicates that a single object's DOM alone might not be sufficient for improving the resource-efficiency of some process – often it will lack the necessary context information and perspective. This issue could be addressed by combining information from several DOMs to an information collective. In the following, this idea is illustrated for selected application scenarios.

2. APPLICATION SCENARIOS
Production. Context adaptive networking of DOMs and their infrastructure may support a holistic view on production processes and thus optimize factory systems beyond the borders of technology, human resources, organizations and time. In production environments DOMs of equipment offering **fine grained information about energy consumption** as well as DOMs of products describing the production history may form the basis for a high resolution management process on the enterprise planning level. Going further, this enables the implementation of **context sensitive production process controls.** Based on the combination of several DOMs information the production schedule can be optimized to require fewer resources regarding constraints like production output, working load, or utilization degree. From the point of view of enterprise resource planning, process and product related energy balances and optimization potentials are of special importance. The combination of products' and equipments' DOM information can deliver a product centered energy balance and realize **super ordinate energy demand optimization** structures

Maintenance. Maintenance processes consume resources in various ways – and can benefit considerably from DOMs. For instance, detailed records of a device's actual usage could support a **condition-based maintenance**, which is only performed when actually needed. This way, the need for (potentially toxic) lubricants or replacement parts can be reduced. Going further, the combination of fine-grained real-time data stored in the DOM of devices and tools enables **asset management** in distributed scenarios – even at the consumer's home. Thus, as it is already practiced for modern cars, a DOM can be used to keep maintenance data (e.g., logs of previously performed maintenance actions, descriptions of replacement parts) of a domestic appliance ready. In order to avoid the replacement of the complete appliance, services might exploit this data to assist the consumer in actions needed after a failure – up to the ordering of a replacement part at a store with 3D printer.

Logistics. Huge potential for resource savings can be found in the sector of logistics. For instance, delicate goods like artworks are today usually transported in special transport networks, which co-exist with regular networks – and thus require additional transports. Here, **packages with DOM, modular and reusable sensor packages, goods with DOM,** and **logistic buildings with DOM** allow for integrating those transports in standard logistics networks. As result the number of special transports will be reduced, which effects a direct reduction of energy consumption. In addition, the combination of vehicles' and goods' DOM information can be interpreted to deliver a broad and detailed view of a logistic region like a city center. This view can support logistic services in terms of resource saving. Such **services based on the combination of DOM information in vehicle fleets** may help to reduce the transportation milage, increase the utilization of vehicles and accelerate pickup and delivery processes.

Consumer. Resource efficiency is not only a financial and ecological issue, but also a matter of personal lifestyle. It affects people's everyday life and is tightly connected with topics such as individual mobility, health-care, and consumption of energy and water. Information from DOMs may support resource-efficient behavior – e.g., with **exemplary records of a device's resource-efficient application**. However, such behavior will often mean an additional burden for the consumer – or even be in direct conflict with his or her interests. We believe that the collective information taken from DOMs of objects surrounding the user can be exploited to conclude about the user's resource preferences – and to **explain and motivate resource-efficient actions**. Eventually, this could not only increase the **user's awareness** of this topic, but also contribute to the experience linked with the respective item.

3. RESEARCH ISSUES

These scenarios share the idea of exploiting a DOM's capability to analyze the actual course of some process – and thus to track (and potentially automatically reduce) the resources actually consumed. Beyond, they emphasize the need to combine information from several DOMs involved in a process, and to use that information as input for context-dependent services. Thus, the envisioned kind of support from DOMs would ground on communication, context, and knowledge about resources. Its realization requires research and development in various areas, among them the following ones.

Added-Value Services Through Communicating DOMs. **Context server architectures** are the technical basis to get the desired records out of the set of involved DOM, abstracting from the specific technical realization of DOMs like barcode, RFID or autonomous DOM. The application of semantic technologies shall be reviewed to extract the relevant information of DOM for a goal-oriented resource optimization process. Here, **ad hoc machine-to-machine communication** between different DOMs and resource optimizing services could enable the envisioned information collectives. Known architectures and platforms – such as SOA – have to be adapted to the needs of DOMs. Furthermore, preventing resource consumption before it actually happens requires **goal-oriented, predictive acting** – a capability which goes beyond the plain capturing of information. It has to be reviewed, how DOMs in cooperation with super ordinate control structures could allow objects to become such actors.

Supporting the User in Resource-efficient Behavior. User interfaces have to support resource-efficient behavior in an illustrative and unobtrusive way. Our special interest is in **designing persuasive interfaces**, which exploit physical objects for interaction and feedback, and which link objects and virtual world (and vice-versa) in order to support the exploration of future actions' impact on resources. Here, **interaction models** describing resource-efficient behavior guide the user and motivate and explain the impact of past and future actions – depending on **resource profiles**, which reflect the user's personal preferences concerning the usage of resources in a given context.

User and Application Context. **Perception of contextual information** is required to feed a context model with input about the environment of a given DOM. We see potential in defining a context on the basis of groups of objects: Their sheer presence, their diverse sensors, and their DOMs may provide hints concerning resource-conserving actions. **Modeling context** in such a scenario requires descriptions of parameters affecting the consumption of resources, which can be mapped to the user's resource profile. To overcome the unpredictable complexity of object combinations, they should allow for abstraction and generalization – which suggests modeling using semantic technologies. **Selection of context data** is elementary in order to provide user and system with information relevant for resource-related actions. Thus, methods are needed, which find and extract data from a (collective of) DOMs matching a given context.

4. CONCLUSION

In this paper, we outlined the DOM's potential to increase the resource efficiency of everyday processes. Based on previous and planned work, the article is meant in the very first place to stimulate discussion of this idea. Beyond basic research concerning the DOM, we believe that further attention should be devoted to the communication among DOMs and between DOMs and services. We consider such communication as essential to create an information collective from the DOMs of each object involved in a process, which contributes to a holistic understanding of the overall process and hence the possibility to optimize resource and energy consumption from a global point of view. Here, we see a major challenge in developing a technological basis supporting the dynamic combination of DOMs in service-oriented environments.

5. REFERENCES

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