FM Knowledge Modelling and Management by Means of Context Awareness and Augmented Reality

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ABSTRACT
One challenge for future IT systems in FM is the automatic processing of large heterogeneous and distributed data and their context-based utilization, e.g. in maintenance management. Regarding the user interface, the access via mobile devices constantly gains significance. Reasons are the increase of multi-functionality, the price decline and the benefit to access data at any time and any place.

The lack of the intuitionally understandable presentation of data on mobile devices still represents a barrier for practical use. The search for information in menu bars, tables or PDF files on limited smartphone displays is too time-consuming and requires too much finger precision from a user perspective.

The conceptual paper presents new approaches of information modelling and -supply, which enable the efficient support of maintenance and approval processes in FM. The ongoing research project FMstar, initiated for this purpose, develops concepts and technologies for semantic modelling and linking of distributed life cycle data of industrial properties and their flexible and context-based presentation on mobile devices, through Augmented Reality (AR). Three universities and four enterprises partake in this project, funded by the German Federal Ministry of Economics and Technology.

Keywords
Facility Management, Augmented Reality, Context Awareness.
1 INTRODUCTION
The range of tasks in Facility Management covers planning, execution and optimization of support processes to secure primary processes of a company. Amongst others, the maintenance and the approval of facilities are important fields of activity. Work patterns, which are carried out in these processes, are marked by a high demand for information. Nowadays important information gets lost during the life cycle of a facility and is no longer available for FM-tasks. A sustainable use of life cycle data is hindered by the amount of data, the variety of data format used by the different partners, who are involved in the planning, as well as by different usage of terminology. This is often accompanied by an insufficient reactivity of the FM-staff.

The research project FMstar addresses the question how the realization of FM-tasks can be supported and improved by means of current Information Communication Technology (ICT). Besides approaches to improve the information supply, one focus is mainly set on improving the Human-Computer Interaction (HCI), specifically on the basis of mobile devices. (Figure 1)

These approaches deal with the context-based provision of information and graphical representation by means of Augmented Reality. This paper focusses on approaches associated with the context-based provision of information.

The context-based information supply is concerned with the question, how only relevant information can be provided to users. The relevance of information is defined by the Relevance Theory, in particular through a function of the processing effort and positive cognitive effect. The processing effort reflects the energy, which the recipient needs to expend to comprehend a specific piece of information and to utilize it. If information is particularly important in the
current situation of the recipient, a positive cognitive effect will be achieved, which means the demand of information is satisfied. The higher the positive cognitive effect and lower the processing effort, the higher the relevance of a piece of information. (Wilson/Sperber 2002) Thus the relevance is highly dependent on the knowledge about the user’s situation. If the situation of the user is clear, the subjective and objective information demand can be determined and potentially relevant information be provided. The situation of the user can be specified by the context of the Human-Computer Interaction. According to Dey, context is “…any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves“ (Dey 2000). To describe this context information, various context factors exist. Koch identifies eight categories of context factors: User/person, activity/task, social environment, place, time, information/information sources, IT-environment/devices and the physical environment. (Koch 2010) In conversations between people, context-information is transferred implicitly, without being mentioned explicitly. In human-machine communication, context data must be collected and conveyed explicitly to be taken into consideration. Context sensors capture the parameter values of the context factors. The term context sensor, at this point, means an abstract service to determine a context value and can be represented by a sensor for air humidity, as well as a software service to determine the current task of an FM-technician. The use of this context information to specify the user’s situation is referred to as Context Awareness in the field of ICT. Vice versa, Context Adaption describes the ability to adapt the system behaviour on the basis of context information. (Sitou 2009) The adaption process refers to the provision of information, processing of functions or applications, or configuration of the user interface. (Koch 2010)

2 OBJECTIVE
The objective of the mobile assistance system, which will be developed in the project FMstar, is to provide only relevant information concerning the FM-user’s scenario. Thus, the relevance is the determining criterion for the selection of provided information. Consequently, the interaction between the user and the system should be reduced to a minimum. This can be achieved by an automatic capturing of context information and its AR-based provision. Finally, a complexity reduction and a higher reactivity of the FM-staff will be accomplished.

3 APPROACH
3.1 Developing AR application scenarios
In order to demonstrate the various possibilities of using AR technology in FM and especially maintenance management (MM) six application scenarios have been developed. They show how MM stakeholders can be assisted in their routine business. In the following, two of those scenarios are described in more detail.

Scenario 1: Get familiar with technical equipment
When technicians, owners, or operators are not yet familiar with the built environment and related equipment they need fundamental information on those systems. This information could be provided by FMstar. Technical data, schematic representations, drawings, instructions, etc. could easily be provided to the user. The information can be presented graphically, acoustically, or even in a haptic manner. As a major benefit those information cannot be overlooked thereby helping to prevent failures. This information can assist the user in better understanding the
function of technical systems and their interrelations. In order to understand complex systems on a rather small display surface of a mobile device the user can navigate “inside” the virtual components. The schematic model of the equipment can be viewed from different angles. By overlaying the real system with the virtual one and by providing additional information on the system’s components the user easily understands their structure and function. In this way s/he is supported in his decision making process.

Scenario 2: Equipment know-how across trades
Technicians are supposed to understand trades outside their own special subjects. Only then they are in a position to solve problems that relate to more than one trade. By highlighting components on a mobile AR system, interconnected parts can be displayed across the respective trades. For instance, this filter function allows to locating a certain HVAC component that is controlled by a building automation system. Consequently, a technician is able to find a ventilation damper in a building without detailed know-how of HVAC systems and at the same time to check the function of the ICA (instrumentation, control and automation) system.

Additional AR scenarios might be:

- Inspection and approval
- Troubleshooting
- Training
- Routine maintenance

3.2 User requirements on AR utilization in FM
As one of the initial steps within FMstar a user requirements analysis was conducted based on an online survey. 16 selected partners from different industries took part in the survey. The questionnaire was addressed to companies from the fields of maintenance, planning, and inspection/approval. The survey focussed on verifying the potential benefits of AR and the definition of application scenarios.

Day-to-day work in maintenance, inspection and approval is characterized by a number of obstacles. In the survey the respondents addressed missing information to be the most serious problem when maintaining, commissioning or repairing technical installations. This concerns completeness, location and maintenance of relevant data. Consequently, we can find dysfunctional maintenance programmes due to the lack of information. The majority of respondents claimed user interfaces of current systems to be too complicated and not user-friendly enough. Furthermore, they stated that important information such as memos and notes are overlooked frequently resulting in unnecessary effort and cost.

The assistant system to be developed within FMstar is intended to reduce or overcome the obstacles mentioned. The survey introduced the participants to various application scenarios, as mentioned in chapter 3.1. They rated both the frequency of appearances and possible benefits of these scenarios on a scale from 1 to 6 (1=best, 6=worst).
Figure 2 displays the corresponding results. Obviously, the potential AR users expect the biggest benefits from the scenario “Get familiar with technical equipment”. It turned out that this scenario is the one that prevails in most organisations. The potential benefits of AR in education and training were considered to be rather low. An explanation could be that the participants are with organisations which are not much involved with education and training issues.

As shown in figure 3 all respondents indicated a high need for graphical support especially in maintenance management. Mainly they required the display/overlay of equipment schematics, facility data and instructions. In addition, photos are supposed to be displayed but also taken and interlinked with the corresponding systems or components. In this way, work order management (e.g. failure detection and documentation) can be improved significantly.

44% of the companies stated that they are already using mobile devices with access to the Internet and/or WiFi if available. No one did refuse future utilisation of mobile technologies in FM. This is a major prerequisite for successfully implementing and exploiting FMstar in FM practice.
Furthermore, the survey showed that the majority of companies interviewed are already using CAFM technology (May 2012) or are familiar with its use. A substantial part of information needed for FMstar is already available in CAFM systems. That’s why the respondents support the idea to integrate AR with CAFM and related data bases, which actually will be part of the FMstar prototype development.

In summary, the survey was able to reveal information deficits in current maintenance and inspection/approval processes and to point out potential benefits of AR application scenarios in FM.

### 3.3 Information modelling concerning context adaption

For capturing of context information during a Human-Computer Interaction the following approach was chosen. First, context factors were identified, which describe the usage situation, and classified into context categories (figure 4). In the following, these factors were integrated in a model for context-based information provision for FM processes by means of a mobile AR-application. This represents the current state of context adaption within the project FMstar. The future work steps will be the description of existing interdependencies between context factors and their weighting and modelling in a context model.

**Context factor identification and description**

The selection of the context factors was based on a top-down process analysis of the usage situation “mobile maintenance”. The factors were classified into four context categories. Context sensors capture the present parameter values of the context factors. A context model transforms the set of context parameter values into an information demand. This will be converted into an information request and transferred to an information resource system. In FMstar this is represented by a semantic database (figure 4, eResources), providing an extensive base of information for industrial facilities. After determining the relevant information the result will be provided to the user. In the project this is realised by transforming the data into an AR-image.
Afterwards the user decides whether the information demand is satisfied or a modification of the context parameters will be necessary. From a current prospective there is no mandatory sequence of considered context factors. Implementation algorithm might start with factors with the highest filter effect or with the first available factor parameter. The description of the model for context-based information provision starts with the process-related context category at the right hand-under quadrant in figure 4. This category stands for the determination of particularly the objective information demand in a work context. The user’s role assigns basic responsibilities and information access. By means of a process model, the current task leads to activities, linked documents, objects (e.g. a component of a facility), (IT-) tools or utilities. Additionally, necessary personnel support can be linked. These process-related context factors can be specified by personnel context factors. The set of basic configurations within a user profile could modify the AR-image on the mobile device. Occupational qualification gives hints for the permissibility of an activity, especially when considering event-driven processes e.g. in trouble shooting. Furthermore, the experience of the user regarding a specific activity can be utilised to filter probably known information.

![Figure 4: Model of context-based information provision](image)

Afterwards, the context factors of location and environment reduce the information demand according to the actual work environment (figure 4). This applies among others to the location, the real view section of the user’s tablet computer or the detected distance to relevant objects. The analysis of the environment includes existing objects, people (staff) and parameters of the physical environment but also available IT environment (e.g. services) or documents. Context parameter values of the current session will be recorded in a time context (depicted as “session t₀, t₁”). They will be available for future adaptions of the information demand, to learn from the user’s behaviour.
Example of a context-based information provision based on AR

The following example of context-based information provision using AR in a maintenance process helps to understand the potential of context awareness. A technician wants to start with one of his or her tasks, noted in the schedule. The inspection of a coolant installation for the production of company X is scheduled. The task is part of a process model for the maintenance. The related process leads to information on the facility, to be inspected, about necessary documents, but also essential auxiliaries as well as tools. Initial assistance could be to provide all necessary tools/auxiliaries before executing the task and to provide navigation to the facility. For this set of information, an AR-based information provision is not yet required. In front of the facility, the view section of the tablet computer determines the relevant information by recognizing the real visible objects. The evaluation of the distance to the facility allows a differentiated depiction of data by using information layers. For instance, detailed information will just be visible by closely focusing on a component of the facility. Animations, colouring or simply labelling can be superimposed by textual information such as object attributes (3 bar in figure 5), depending on the required quality of support for the technician. Documents linked with this task can be requested and updated.

This example presents only a small section of potential contexts, which could be incorporated in a system interaction between a FM-technician and a mobile information system. However, it is suitable to demonstrate the potential of context-based information provision by means of AR.

Figure 5: Example of a AR-based assistance system for FM-technicians
REFERENCES


