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Supporting Technical Customer Services with Mobile Devices: Towards an Integrated Information System Architecture

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ABSTRACT

Due to increasing complexity of machines and plants, information tailored to the needs of Technical Customer Services (TCS) is a prerequisite for the execution of efficient service processes. This paper describes the conception of a supporting architecture incorporating an integration platform to meet the TCS' demand for information. On the one hand, the developed architecture directs the integration of data from different specialized systems to cover the aforementioned information needs. On the other hand, it enables the feedback of the TCS to other corporate departments which is often neglected. The system classes to be integrated are presented besides options and technologies for realizing the integration platform. The article creates a framework for future discussions on information technology integration to support the TCS.

Keywords

Technical customer service, information integration, architecture, integration platform.

INTRODUCTION

Product-supporting services are key differentiators in competitive markets and thus are supposed to hold a high value-adding potential (Rai & Sambamurthy, 2006). Recent studies prove their increasing significance for both industry and the service sector. In 2002, sales revenues of product-supporting services totaled 151.6 bn Euros in Germany alone (Mödinger & Redling 2004). Against the backdrop of manufacturing organizations, customized services delivered along with machines, devices, systems or plants are defined as product-supporting services (Mödinger & Redling 2004). The largest suppliers of product-service systems are the electrical (32%) and mechanical engineering industries (28%). Despite the enormous significance of services in today's economies and their high impact on competitive advantage (Mödinger & Redling 2004; Walter et al. 2010), the efficiency of service delivery is still neglected. Though information processing has been acknowledged as an instrument to realize services more efficiently (Platz 1980), for example by equipping the Technical Customer Services (TCS) with mobile devices (Rügge 2007), the full potential of information processing has not been realized up to now. With our design-oriented approach, we propose an approach for leveraging the efficiency of TCS by empowering the service technicians by mobile devices (Bowen & Lawler 1992). The theoretical underpinning of the concept is presented in (Blinn, Nüttgens 2010). In this paper, we focus on the practical assumptions which are introduced in the following section.

BASIC ASSUMPTIONS AND PROBLEM DOMAIN

An overview of the relevant flows of information and communication supporting TCS is illustrated in Figure 1. It illustrates the crucial partners of an extended value-adding chain (Walter et al. 2010) participating directly or indirectly in the product-supporting service provisioning. TCS belongs to the value-adding subprocess "customer service" and is further differentiated into office-based (teleservices or disposition) and field service (at client's site) from a holistic perspective. Partners directly adding value represent R&D, process engineering & manufacturing, warehousing and sales. Quality assurance and accounting/controlling indirectly influence all departments. By now, numerous highly specific application systems support the service technicians during their different maintenance activities (Rügge 2007). As the information systems work independently and store their data separately, the potential of the qualitative and quantitative information available is not fully used. Since the objects of maintenance become more and more complex and diversified at the same time, the TCS suffers from an information overload e.g. due to the size of manuals (Thomas et al. 2007). Subsequently, the negative effects of poorly integrated systems can be summarized as follows (Thomas et al. 2010):

1. Systems for mobile usage by the TCS at the customer site are not available at all or only in a restricted manner.

2. Subsystems are frequently isolated forcing the TCS to switch applications in a time-consuming and error-prone way.

3. Discontinuity of medium and application lead to redundant respectively faulty data entry.

4. Updating TCS information is costly and delays can cause wrong decisions of the TCS due to outdated information on-site.

According to the presented challenges, an adequate integration platform is required to link existing systems in order to meet the information demand identified (see Figure 1). Main aspects of this integrative hub are the determination of information requests and resulting needs, the search and provision of the needed information and the preparation and allocation for its use on dedicated devices. In the article at hand, a suitable architecture for realizing this integration platform is developed to support information exchange between the value-adding partners (Walter et al. 2010) and to meet the practical TCS requirements (cf. paragraph "Requirements for the System Architecture").

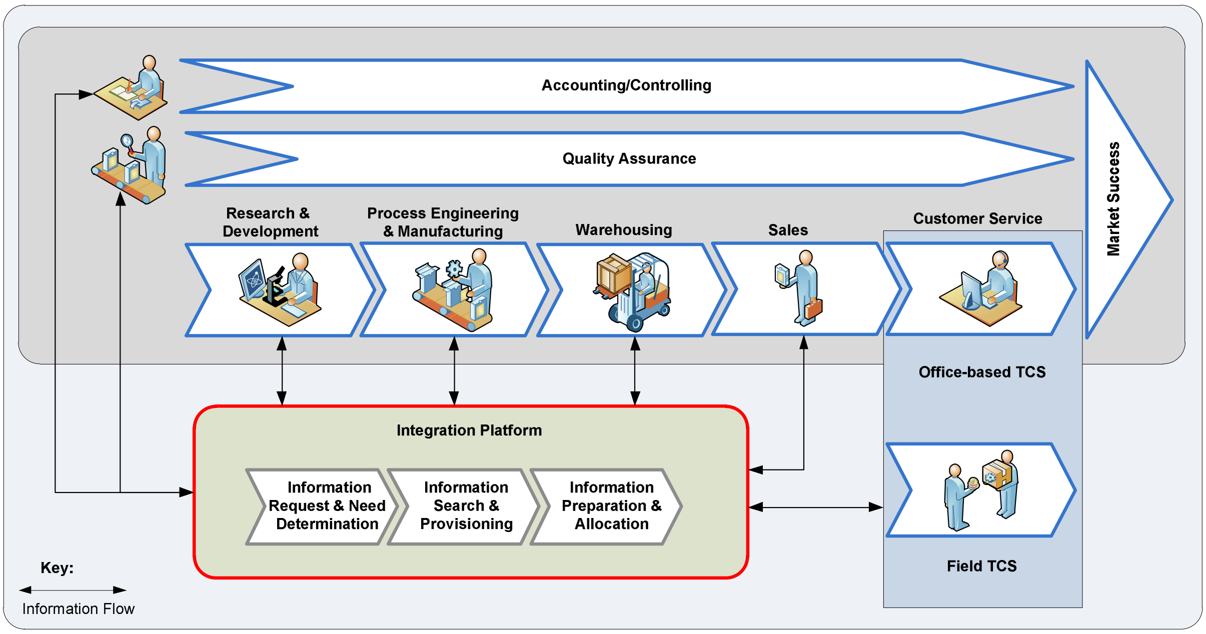

Figure 1. Integration Platform and Information Flows of the Enterprise

INFORMATION INTEGRATION IN TCS

Information Systems

An information technology-based support of the customer service processes is today provided for manifold, heterogeneous systems and plays an important role in practice. Nevertheless, type and scope of the components and sub-systems vary significantly. Thereby, some systems contain complex components of expert systems or knowledge management systems, while others merely include integrated documentations. The information system classes which are most frequently used in business practice are knowledge management systems, maintenance planning and control systems, condition monitoring systems/monitoring systems, diagnostic systems as well as parameterization systems (Thomas et al. 2010).

Knowledge Management Systems (KMS) are applied to store data about machines and to retrieve the data if needed. Furthermore, they help to optimize the TCS and are used for product development. The tremendous importance for the TCS is due to the severely growing complexity of technical machines on the one hand, and the increased requirements by the machine operator imposed on the TCS on the other hand (Weinrauch 2005). In this respect, the problem is that due to the semantic and structural heterogeneity of the data that has to be integrated – for instance, service mauals, repair guidelines, data sheets, spare part lists, best practice reports – KMS often represent stand-alone solutions and are not able to integrate all the necessary data. In addition, often, these systems cannot be accessed when the TCS is on-site. This complicates repair processes on the one hand and the analysis of data originating during the work on-site on the other hand. The latter could also be used for the improvement of the production or the products.

Condition monitoring systems/monitoring systems (CMS) are employed for the monitoring of machines. Such systems allow for the recording and evaluation of the machine condition, thereby providing for the generation of early diagnosis or the prediction of defects (Weinrauch 2005). Mostly, they play an important role in conjunction with teleservice solutions concerning machines and systems which are not constantly supervised by technical personnel.

Diagnostic systems are based on the data which is provided by condition monitoring systems. Their intention is to detect error causes independently or to support a system user during the search for such causes. On top of that, they assist the user as an advisory system (Thron et al. 2008). Due to the complexity of technical machines and products, especially in the automobile sector, diagnostic systems are frequently applied and often even prescribed (Weinrauch 2005). However, it is problematic that a huge amount of the data collected by the diagnostic systems cannot be used for the improvement of the production or the products as they cannot be accessed by the respective recipient in the production or the product development department.

Parameterization systems (PS) are used for the parameterization, i.e. the adjustment of machines. Merely by parameterization, errors and failures may be eliminated – provided that they are not caused by hardware problems. However, PS do not only support the TCS staff, but they can also support the machine or system operator with the adjustment of the machine. A problem in this respect is that the knowledge concerning the optimal parameters for a certain purpose often only exists in the minds of the service technicians and that it has only sparsely been externalized and formalized in the utilized knowledge management systems as PS and KMS are not linked with each other.

By means of a classification scheme for integrated information systems of the TCS, Thomas et al. (2010) examined 16 application systems. This was done by taking the aforementioned system classes into account. The study revealed that none of the offered systems covers all system classes. In addition, they are solely targeted – with a few exceptions – at the support of a single company department: the customer service. An operational support of the TCS is not provided by the majority of the systems. Likewise, there is a lack of expert systems that can support the employees during the decision-making process.

Up to now, especially the integration of further partners into the value chain has been neglected as well as a process-oriented assistance function that is complemented by expert system functionalities. The architecture which we systematically derive and unfold in the remainder of this paper is intended to fill these gaps as well as those identified in the section "basic assumptions and problem domain". The presented requirements for the system architecture additionally have been validated by intensive discussions with a leading enterprise of the technical consumer durables industry.

Requirements for the System Architecture

In order to achieve an integrated supply of service information, an appropriate data and knowledge store is required. This data store forms the basis for realizing the functionalities of the information system which is to be created. Beyond the merely technical accessibility and usability of the data, also the requirements of the concrete situation and context where the data is used are of great importance. The TCS should be able to access relevant data when they are needed most urgently: when the technician is on-site at the customer's facility. In this situation, the TCS should have mobile access to the information enabled by appropriate devices (Thomas et al. 2007).

In the other direction, it should also be made possible that data which has been collected during the work of technicians on-site is used in other departments than the customer service department. The derivation and direct provisioning of aggregated data for planning purposes enables the production department to react more quickly to deficiencies related e.g. to the assembly of the products. Moreover, also the product engineering department can benefit from the derived information in such a way that the creation of new products is influenced by the insights distilled from the aggregated operative service data. In this regard, statistics reflecting error-rates of components and assemblies can lead to the detection of potential product improvements or cost reductions.

Using an integrated system as it has been envisaged above and which spans the whole value creation chain, the measurement and assessment of TCS productivity should be enabled in the future. However, up to now neither consensus in regard to the meaning of the term *productivity* concerning service processes is reached, nor are there any widely agreed procedures to calculate this measure (Baumgärtner & Bienzeisler 2006).

The requirements implied in the above descriptions can be aggregated to the following:

(R1) Integration and transformation of heterogeneous data and information assets

(R2) Mobile access to service information

(R3) Derivation of data for planning purposes

(R4) Derivation of data for product engineering

(R5) Measurement and assessment of productivity

ARCHITECTURE OF THE INTEGRATION PLATFORM

Based on the given requirements in the previous section, the fundamental elements of the architecture are derived in this section. The derivation is accomplished systematically by considering the requirements (R1-R5).

Elements of the Architecture

An important element of the architecture (for a graphical representation, see Figure 2) is a centralized *data and knowledge base* (R1) serving as a basis for storing consolidated and consistent data and knowledge assets which are a prerequisite for realizing the functionalities of the new system. In doing so, the data of the already *existing application systems* should not merely be duplicated. Instead, they should be transformed and processed in such a way that new applications and usage scenarios are possible which have not been intended or even foreseen by the creators of the *existing application systems*. Hence, it is not sufficient to access the existing systems in an ad-hoc manner when a need occurs. Rather, a separate *data and knowledge base* for storing transformed and consolidated data assets is introduced thereby also removing possible performance bottlenecks which may arise accessing the *existing application systems*.

The process of integrating and transforming data is directly connected with the import of data from the *existing application systems*. In this way, a consistent *data and knowledge base* is enforced right from the start when the data and information are imported into the system. In addition, methods and technologies developed in the realm of the Artificial Intelligence (AI) discipline such as description logics, rules and approaches of information extraction are added to the subsystem *semantic data integration and processing*. This subsystem is used to systematically extract the information contained within the imported data.

The *TCS assistance system* provides the services of the information system to the employees of the TCS department. The services can be accessed either by *mobile clients* (R2) or by *stationary computers* such as workstations. The modalities and functionalities for searching and displaying information thereby have to be adjusted to the demands of the service technicians and to the requirements of the usage scenario. They might encompass approaches for visual exploration and search as well as leveraging strong problem solving knowledge achieved by embedding functionalities of expert systems.

The integration platform moreover has to provide *basic services for collaboration* in order to enable and augment networking and exchange of experiences and best practices among the service technicians. To boost the collaboration, services such as discussion groups, comments as well as tags and ratings for content assessment are necessary. The user generated data gathered by the collaborative features is also stored in the central *data and knowledge base*. Combined with the features of the subsystem for *semantic data integration and processing*, the aggregated user generated content can be used to derive new facts concerning the objects already represented in the *data and knowledge base*. As an example, an added fact might be of this form: "The repair manual *x* is used in 80% of the cases for successfully repairing defect *y*". These facts derived e.g. from user ratings can be used in turn to improve the recommendations and suggestions given by the *TCS assistance system*.

Besides the direct support of the TCS by the *integration platform*, other departments should also benefit from the platform in such a way that relevant feedback and reports are generated which can be accessed by demanding departments. Therefore, a subsystem is necessary providing *semantic data analysis and export* in order to fulfill the specified requirements (R3-R5).

Structure of the Architecture

As a fundamental paradigm, the client/server architecture has been selected as this architectural style is already used in the realm of process-oriented systems in TCS (Schlicker & Leinenbach 2010). Architectural concepts which are more geared towards flexibility and the loose coupling and exchangeability of components such as the Service Oriented Architecture paradigm are less suited. This is the case as, contrary to the notion of loose coupling, the subsystems of our proposed architecture strictly depend on each other. Another architectural concept would be the architecture of a distributed system such as a server cloud or a server grid. However, distributed systems emphasize aspects such as scalability and load distribution which are of less importance as our main interest is creating an architecture for supporting the TCS of single companies.

The main elements of the architecture are the *integration server* and the *mobile client* (PDA, laptop or other devices) of the TCS. The *integration server* receives data from the *existing application systems* as well as from the customer service, either via the *mobile client* or by entering the data directly e.g. from a *stationary computer*. In the opposite direction, the *integration server* also delivers integrated and transformed data to serve the various information demands not only from the TCS either via a *mobile client* or a *stationary computer*.

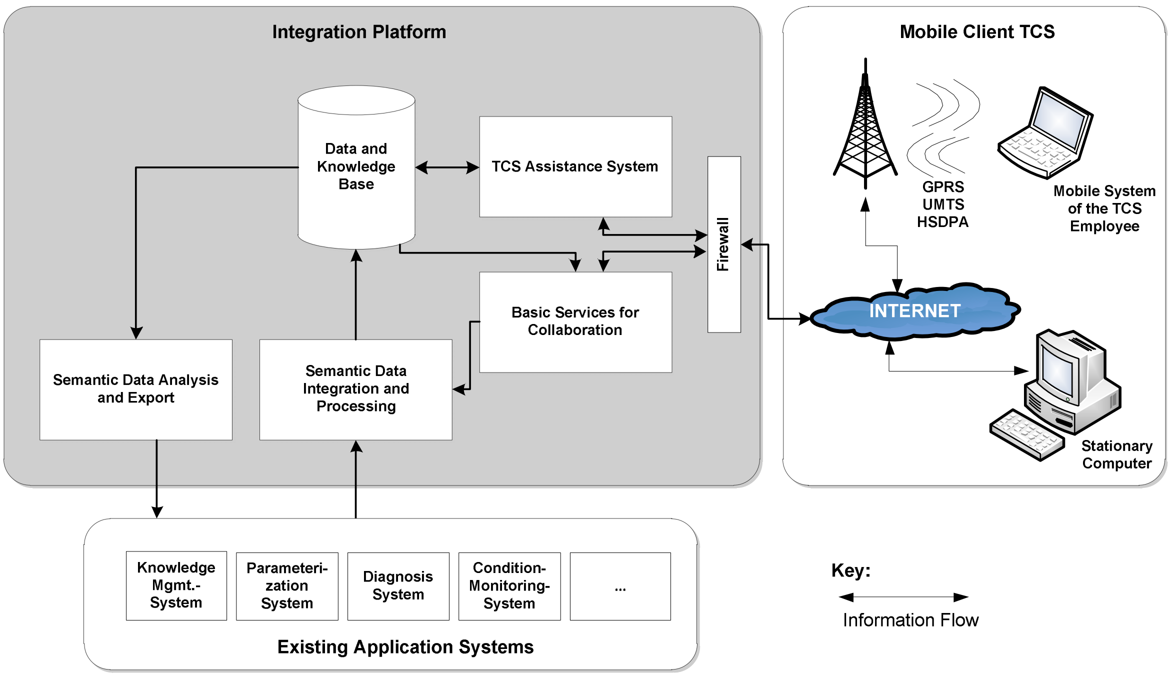

Figure 2. Architecture of an integration platform supporting the TCS

The *integration server* consists of the following components:

- Basic services for collaboration,
- TCS assistance system,
- Data and knowledge base,
- Semantic data integration and processing,
- Semantic data analysis and export.

The subsystems interacting directly with the *mobile client* are thereby the *basic services for collaboration* as well as the *TCS assistance system*. The employee accesses these systems to both receive the required information and maintain or extend the data in the system (e.g. to supplement error codes with detailed descriptions). The *TCS assistance system* can add such newly created facts which result from its usage e.g. on-site at the customer's facility directly to the *data and knowledge base*.

In contrast, data created by the usage of the *basic services for collaboration* are added to the *data and knowledge base* by additionally passing the *semantic data integration and processing* subsystem. With this additional processing of data, unstructured texts such as they are present in discussion systems, tags or ratings can be transformed and pre-processed in order to make them more valuable and usable by the *TCS assistance system*. Examples for such processing steps would be the extraction of information from unstructured texts or the aggregation of tag and rating information. Additionally, the *semantic data integration and processing* subsystem serves to import and extract structured and unstructured data residing in the *existing application systems*.

The *semantic data analysis and export* subsystem is based on the integrated *data and knowledge base* and is used to generate reports for other departments of the enterprise. It may also be used to generate data for use in other application systems.

To sum up the description of the architecture, the developed architecture provides a generic blueprint for enterprises with TCS departments facing the problems we have described in the requirements section. On account of the prominent role of the *data and knowledge base*, methods and technologies focusing the input and output of data are of significant importance in order to put the architecture to work in practice. We hence elaborate on semantic data integration in the next section.

SEMANTIC DATA INTEGRATION

Semantic methods and technologies play a vital role in regard to the proposed architecture as they enable to unveil the information contained in (unstructured) documents or that are locked in structurally heterogeneous data assets. The ultimate goal is to provide one consolidated view encompassing the data of existing application systems as well as the data of documents such as repairing guides, manuals, data sheets etc. This integrated data should be usable e.g. for querying or reporting via a unique interface. From a technical point of view, the data and information assets which should be integrated can be characterized in respect to the degree of their structuredness as unstructured, semi-structured or structured. In the following, we describe methods and technologies for structured and unstructured data – semi-structured data can be processed by combining methods and technologies of these two areas.

Integration of Unstructured Data

In order to integrate and process unstructured data, robust methods for the extraction of partial structures and their contents are required. Examples of unstructured data are manuals, repairing guides as well as informally described experiences or best practices. The majority of unstructured information is thus textual content which is amenable to text processing and extraction tools. Text extraction enables e.g. to recognize and index the technical procedures suggested in a repair manual or corrective maintenance guide and to catalog these procedures e.g. by involved spare parts or components. Whereas commercial offerings for text extraction such as the *SemanticHacker API* often confine themselves to recognize only a few information units such as characteristic keywords or named entities, tools originating from a scientific background offer advanced methods to extract structures such as ontologies from texts (Maedche 2002; Haase & Völker 2005).

Integration of Structured Data

The integration of structured data can be resolved by the mapping of heterogeneous schemata describing the data. Approaches to schema matching (Shvaiko & Euzenat 2005) support the user in mapping elements of two or more different schemas onto each other. The notion of "schema" thereby is interpreted in a wide sense comprising also database schemas, xml schemas, taxonomies, ontologies as well as other structures such as controlled vocabularies. A general overview over schema matching tools is provided by (Do et al. 2002). At present, commercial tools such as the *BizTalk Mapper* from Microsoft, *MapForce* from Altova or *Stylus Studio* of the correspondent enterprise support the user mainly in creating mappings manually. Of particular relevance in respect to the *integration platform* for the TCS are tools that support a wide variety of schema languages. An example of such a tool is *COMA++* (Aumueller et al. 2005) supporting XML schemas as well as ontologies and relational database schemas. Another tool, *XBenchMatch*, explicitly serves as a benchmarking system for comparing the quality and speed of different mapping approaches (Duchateau 2007) and therefore can be used to evaluate approaches for structured data integration.

Due to a limited time budget of the TCS employees and in order to increase the acceptance of the newly created information system, approaches increasing the level of automation in creating mappings have to be considered. These approaches operate on the basis of a set of input mappings (examples) and/or use machine processable background knowledge (Madhavan et al. 2001). In this direction, it should also be investigated if methods and technologies for the mapping, merging or alignment of formal ontologies (Hameed et al. 2004) can be leveraged in the TCS context. Use cases for such approaches are not only the integration of heterogeneous schemata, but also the integration of the structures resulting from the extraction of unstructured data (cf. previous section). A tool for ontology-based schema matching is for example *Chimaera* (McGuinness et al. 2000). The tool supports the construction of a global ontology from different partial ontologies as well as the analysis of the resulting schema or ontology. As a middle ground between manual mapping and fully automated procedures, some tools also allow for an interactive mapping such as *PROMT* (Noy & Musen 2003).

USE CASE

In this section, a simplified use case is used to illustrate how an information system on the basis of the above architecture can support TCS and the corresponding organization in general. For this purpose, the repair of a malfunctioning forklift truck serves as a practical use case.

In order to enable TCS employees to submit on-site requests to the system, it has to provide the relevant data. Initially, the operating instructions, manuals etc. of all components (engine, hydraulic system etc.) have to be gathered and to be imported using the *semantic data integration and processing* module. The *TCS assistance system* could use that data subsequently to support the technician in the repair process. Resources already stored in the *knowledge base* can be accessed due to the semantic linkage of related terms (e.g. repair reports of different engine types, potentially providing transferable solutions).

Now, the employee can use the *TCS assistance system* to submit a request concerning the malfunctions occurred. Assume, for instance, there is a defect in the hydraulic system. First of all, the assistance system queries the data and knowledge base and returns a solution proposal. If it does not fit the underlying problem exactly, the TCS employee has two options. On the one hand, he or she can extend the search to semantically similar topics. A hereby found result could then be used by the *TCS assistance system* to autonomously improve retrieval. On the other hand, the technician has the possibility to add newly found solution strategies to the database or to participate in discussions on (partially) unsolved problems. This corresponding functionality is part of the *basic services for collaboration*. Again, the retained, unstructured data are processed by semantic methods prior to database storage.

Finally, other departments of the organization could use the obtained data for analysis and reporting purposes by stating structured request. In this way, semantic data analysis allows for inferences on contextual error frequencies for instance. A defect encountered among all components produced on the same machine can therefore trigger an appropriate revision by the production department.

CONCLUSION

The presented architecture has been developed considering the requirements described in the requirements section. An essential merit of the proposed architecture is to direct the implementation of a corresponding information system and as a consequence enabling the integration of the different systems used in the TCS (R1). Further, the architecture reflects both information supply of the service technicians when they are on-site at the customer's facility (R2) and information production by the service technicians captured by collaboration services. Applying this architecture, not only the needs for information of the TCS can be satisfied but also the needs for information of other enterprise departments (R3-R4). In this way, the basis for an evaluation of the productivity of the service processes of the TCS is achieved (R5).

The independent data and knowledge constituting an essential element of the integration platform inevitably leads to the storage of redundant data. However, this disadvantage is counterbalanced by the fact that operative systems are unburdened from frequent data access and from being intertwined in numerous interfaces. Similar considerations lead also to separate data stores in the realm of data warehousing. Regarding the proposed architecture, a separate data store also offers new possibilities for the purposeful structuring and organization of the data fostering their later use e.g. by mobile devices.

Finally, the presented architecture has been heavily influenced by an intensive exchange of ideas with a leading enterprise of the technical consumer durables industry in the context of the research project EMOTEC funded by the BMBF. The architecture is currently applied in the project and the integration platform is under active development. In the future, we will further evaluate the architecture proposed in this paper and identify critical success factors for its application.

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