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Retrieving knowledge and information by using a systematic search interface – an industrial case study

Thomas Luft, Sandro Wartzack
Chair for Engineering Design
Friedrich-Alexander University of Erlangen-Nuremberg (FAU)
Martensstraße 9, D-91058 Erlangen
GERMANY
luft@mfk.uni-erlangen.de

Abstract
Knowledge and information are nowadays the most important factors for the development of modern and innovative products. Therefore the efficient management and contextual supply of knowledge is nowadays becoming increasingly essential because more knowledge and information needs to be considered by engineers. However, there are a variety of problems in handling and retrieving knowledge and information in particular in the engineering design process. Existing IT systems do not meet the requirements of the users or do it only in an insufficient way.
In this paper which is based on an industrial case study the identification and in particular the classification of "Knowledge and Information-Objects" of the considered company is described. These two steps are one of the most important preconditions for a holistic and computer-based knowledge management system from a management and a supply oriented view. In order to customise a systematic search interface that meets the requirements of the employees, an appropriate number of workshops with experts from different departments have to be organised. The focus of this paper is on a (combined) content- and source-based systematic search interface for knowledge and information retrieval.

Keywords: knowledge management, product development, requirement analysis, information storage, information retrieval, industrial case study

Background and motivation

According to a poll, the vast majority of companies estimate that the share of the factor "production knowledge" is over half of the value added of an enterprise [1]. Furthermore, almost every polled company rated the importance of knowledge management with "high" or "very high". The factor knowledge and information has especially in the product development process a decisive impact on the final product [2] [7]. Therefore it is nowadays a key element for an efficient product development process to retrieve the right and contextual process- and product knowledge of high quality in due time. A recent study has shown that the lack of knowledge and information, in particular in early product development phases leads to additional costs for a company of $ 20 per employee per day [15]. According to recent empirical studies from the USA, designers spend ten percent of their time on the search for knowledge and 38 percent for the inquiring of information from colleagues and experts. The interpretation and adaptation of identified knowledge requires additional 46 percent of their working time [4]. These figures indicate the importance of an efficient knowledge management system in the product development process [4].

Problems in retrieving and handling knowledge and information

The rapid spread of information and communication technologies has entirely changed the way how knowledge and information is created, shared and stored [18]. Due to these continuously evolving technologies the volume of digital information is rapidly increasing in recent years [13]. In 2002 alone, about five billion gigabytes of new information were created worldwide, according to a study that has been conducted by the University of California, Berkeley [10]. According to HUBKA is the design engineering and product development process predominantly a knowledge and information handling process [6] and therefore in particular engineers and product developers are not only more and more confronted to deal with this flood of information but also to retrieve useful information from different knowledge and information management tools [8]. A survey of 27 engineers from various industries and enterprise sizes showed that a total of 61 systems are used by the respondents [11]. As a result, the employees have to retrieve their required information from several tools, such as emails, spread sheets, digital calendars, paper-based logbooks, PowerPoint presentations, document management systems, PLM systems, specific databases, paper folders, informal meeting notes, Post-it Notes, the Internet, etc. [11].

Research question and objectives

The purpose of this paper is to identify requirements for a knowledge management system of a special engineering company in the optical and opto-electronic industry. These requirements are the prerequisite to develop a concept for an efficient and contextual management and supply of knowledge and information – not only for the considered enterprise in the case study. The main focus of this paper is to answer the question how the identified knowledge and information can be structured from a management and in particular a supply oriented view in order to reduce the time for retrieving knowledge and information. Some preliminary work, that is important for the following paper, to identify, classify and analyse requirements for a knowledge management system is explained in [9]. The overall objective is that product development processes can be accelerated and development costs can be reduced and product quality can be increased with a suitable knowledge management system [5] [12] [15].

Procedural method and content

To achieve these objectives, the basic theoretical foundations are described in the following section. It focuses on the topics of knowledge (e.g. definition and distinction of knowledge), the definition of "Knowledge and Information-Objects" (KaI-Objects) as well as on the importance to classify and structure knowledge and information [3]. Based on this theoretical foundation the methodical identification of knowledge and information in an industrial case study is elucidated. Afterwards the authors conducted moderated workshops with experts from different departments (e.g. design, quality management, metrology, development, procurement) in order to take all opinions into account. Based on the experiences and lessons learned from these workshops, three customized search interfaces to users' needs will be developed. In this paper only the (combined) systematic search interface will be presented. After a brief evaluation of the methodological approach and a critical discussion of the mentioned search interface, the last section summarizes the paper and outlines future research and work in order to implement an integrated knowledge management system which consists basically of the management functionality (management view) and the searching functionality (supply view).

Fundamentals and related approaches

In the following section relevant fundamentals and related approaches which are the scientific background of this paper will be explained and discussed.

Definition and dissociation of knowledge

First of all, the question "What is knowledge?" (cf. [16]) will be answered, as only thereby an efficient management of knowledge is possible. Because of the difficulty of giving a uniform and precise and definition of the term knowledge and since no other approach to define knowledge will be developed, this paper is based on the following, relatively prevalent and pragmatic definition by PROBST [13]: “Knowledge is the sum of all (cognitive) abilities and skills that are used by individuals to solve problems. This includes not only theoretical insights but also practical everyday rules and routines as well as instructions. Knowledge is based on data and information and is in contrast to them always tied to specific individuals. It is constructed by individuals and represents their expectations about cause and effect interrelations.” This definition of of knowledge management shows that the knowledge management goes beyond the mere management of data and information.

Besides this definition of knowledge, it is useful to draw a distinction between character, data, information, knowledge as well as to reveal the relations between these terms [7]. The lowest hierarchical level contains a large stock of all kinds of characters, such as letters, numbers, special characters and symbols (e.g. “1”, “5”, “6”, “$”, “€”, “.”). Data can either be a sequence of characters (e.g. character strings) or individual characters. Through order rules, such as a syntax or code, characters are linked together and set in relation to each other and this consequently leads to data (e.g. “1”, “1.65”). The next level in the hierarchy, information, is data that is placed in a context and is interpretable as a result. Consequently, information is resulting from the integration of data into a specific context or into a semantic context of meaning [13]. Knowledge is created not (yet) by a mere collection of information. Therefore, knowledge is rather the result of complex refining process of information. In this process, the selected information is consciously filtered according to certain criteria, compared, evaluated, interconnected and correlated with each other. This knowledge creation process can be influenced, among other things by the cultural background and individual experiences and cognitive expectations of an employee [13].

Definition of “Knowledge- and Information-Objects”

With the help of so called “Knowledge- and Information-Objects” (KaI-Objects) the entire knowledge and information base of the company which is examined in the case study can be identified and analysed. The definition of the KaI-Object includes the following aspects:

- Each KaI-Object can be associated with at least one specific knowledge carrier and a knowledge carrier can ordinarily have several KaI-Objects.
- A KaI-Object can not only include explicit but also implicit knowledge [7].
- In general KaI-Objects can contain knowledge as well as skills, abilities, experiences and partially also attitudes and behaviours of individuals or teams.
- A KaI-Object can be both input (e.g. knowledge which is required) and output (e.g. knowledge which is arisen) of knowledge activities (e.g. process step, work task).

In summary, it can be stated that KaI-Objects are an abstract class of similar knowledge and information. These KaI-Objects are characterized by the following figure (figure 1) [9]:

KaI-Object		
	Content	➢ i.e. description, scope and demarcation of the content
	Type	➢ i.e. the chosen analog or digital (data) format (e.g. paper size, word document)
	Location	➢ i.e. where it is stored or can be found (e.g. in database, head of employee)

Figure 1 Characterisation of KaI-Objects

The significance of the classification of KaI-Objects

To enable an automated, computer-based and contextual knowledge management system appropriate approaches of knowledge representation have to be developed [17]. These forms of knowledge representation can be modelled among others by taxonomies, thesauri, hierarchical or networked ontologies (e.g. knowledge and topic maps) [15]. For this is the classification of the complete knowledge and information base (equal to all KaI-Objects) of the company a necessary prerequisite.

A classification of the KaI-Objects can be achieved through a standardized storage system, metadata mapping or with the help of an appropriately structured classification scheme. The KaI-Objects that have been identified in the mentioned industrial case study (cf. [9]) have to be classified according to a specific classification principle (e.g. after certain criteria). The resulting levels are classes of KaI-Objects with common or similar characteristics. Thereby the drawing of clear distinctions, which are not only specifiable but also differentiable, between these classes plays a decisive role. Indeed, experience from practice has shown that the classification of KaI-Objects into certain classes is very time-consuming and problematic. Nevertheless is the requirement "Classification of identified KaI-Objects" according to a specific systematic classification one of the most significant ones for the development of a knowledge management system in order to manage and to retrieve knowledge and information of the company [4].

Methodology for the development of the systematic search interface

In this section the approach for the identification of KaI-Objects is briefly presented (cf. [9]). Afterwards the classification of all identified KaI-Objects according to certain criteria is explained. The classification is ongoing discussed in moderated workshops in order to involve employees from different departments. Based on these experiences and lessons learned the customized (combined) systematic search interface is described.

Identification of KaI-Objects

The following three analysis methods were used in the industrial case study [9]:

- Document analysis: All management systems are searched for KaI-Objects
- Expert interviews: Individual experts are interviewed about their activities and the associated KaI-Objects
- Moderated workshops: Employees from different departments discussed in order to identify also all KaI-Objects along the product development process

The following figure shows the methodological approach for the identification of KaI-Objects as well as the collected additional information for each KaI-Object (figure 2).

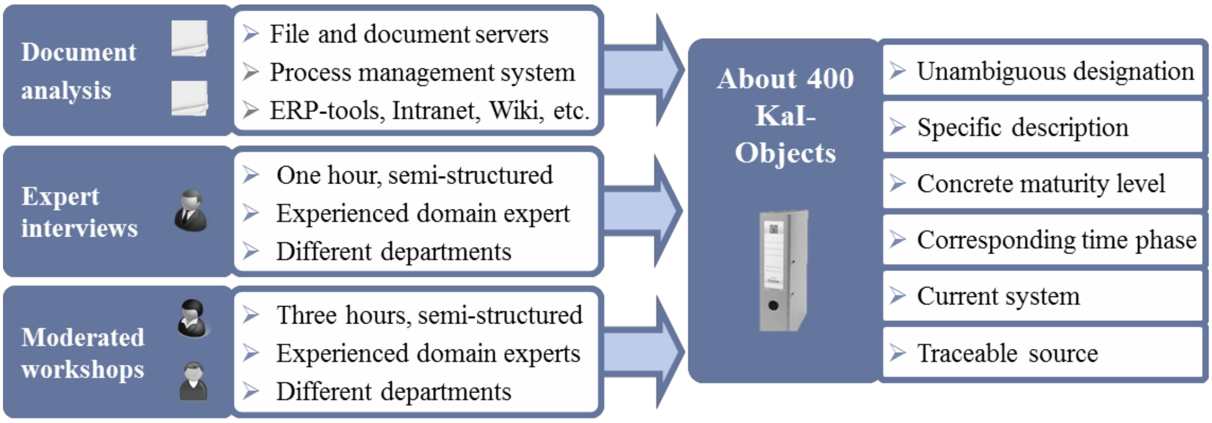

Figure 2 Methodological approach for the identification of KaI-Objects

Classification of KaI-Objects

After identifying all KaI-Objects that were gathered by analysing documents and conducting expert interviews as well as workshops, these have to be classified in the following step. Based on insights and experiences derived from the aforementioned conversations with several engineers, it became apparent that the employees of the considered company are mainly searching content- and source-oriented for knowledge and information. As a consequence of this habit, all KaI-Objects were classified according to a content-based systematic as well as a source-based systematic classification. In addition to these two principles of classification, all objects are also classified after an organizational structure view and a document type view which are, however, not discussed in detail in this paper.

For this reason, two classification schemes have to be developed in each case with several superior and subordinate classes. The determination of these classes is done by the use of specific characteristics. These must be clearly distinguished from other classes, so that every single KaI-Object can be mapped to a certain class uniquely and as clearly as possible. The around 400 KaI-Objects that were identified in the case study were classified according to a content-based systematic classification (e.g. product-, process-, methodological-, company- and manufacturing technology-related knowledge) and according to a source-based systematic classification (e.g. document/explicit or empirical/tacit knowledge, internal or external knowledge, project-related and project-unrelated knowledge).

The two systematic classifications shown below were evaluated by a workshop with experts from different departments. An important question for the workshop participants is whether they find any items that do not fit into the classification scheme (content-based and source-based systematic). Another central question is whether the searching of KaI-Objects by using these two classification systematics is intuitive and efficient enough. The findings gained from these discussions are incorporated in the subsequent revision of the two classification schemes. It has to be noted that a classification systematic that takes into account all the different opinions and views of different employees is not possible at all. Afterwards the classification scheme is re-evaluated by several experts as well as the department heads. Through this iterative adjustment and approval process, the following two systematic classifications have been created (figure 3 + 4).

Hierarchical level 1	Hierarchical level 2	Hierarchical level 3	KaI-Objects
Product knowledge			
	Product requirements		
		User requirements specificat.	
		Design for X requirements	
	Construction technology		
		Technical drawing	
		CAX knowledge	
	Metrology		
		Electrical metrology	
		Ultrasonic metrology	
	Product configuration and structure		
Process knowledge			
	Process requirements		
		Corporate management proc.	
		Corporate quality procedures	
		Corporate work instructions	
	Process description		

Figure 3 Content-based systematic classification (extract)

Hierarchical level 1	Hierarchical level 2	Hierarchical level 3	KaI-Objects
Document/explicit knowledge			
	Internal knowledge		
		Project-related knowledge	
		Project-unrelated knowledge	
	External knowledge		
		Project-related knowledge	
		Project-unrelated knowledge	
Empirical/tacit knowledge			
	Internal knowledge		
		Project-related knowledge	
		Project-unrelated knowledge	
	External knowledge		
		Project-related knowledge	
		Project-unrelated knowledge	

Figure 4 Source-based systematic classification (extract)

Customising a systematic search interface

Based on experiences and lessons learned from the workshops and discussions the customisation of a (combined) search interface to users' needs will be described in this section. In order to meet the requirements for a user-friendly and exactly to the employees' needs adapted systematic search interface, it is necessary to consult as many employees from different departments as possible. Regarding the content-based and the source-based systematic search interface all the needs of the staff is collected and then taken into account during the development of a first mock-up. A significantly simplified extract of the combined systematic search interface is shown in the following figure (figure 5).

The great advantage thereby is that an employee can search simultaneously in multiple hierarchical levels and as a result it is possible to locate the desired KaI-Objects quicker and more aimed. The reason for that is that it is possible to search for KaI-Objects in the intersection between two or more different systematic classification and hierarchical levels by the execution of logical operations such as “and” and “or”. By selecting the two hierarchical levels “Technical drawing” and “Project 1000” and the logical operation “and” (not shown), for example, only these KaI-Objects will be shown that have been mapped to the two selected hierarchical levels. As a consequence the number of KaI-Objects is significantly reduced.

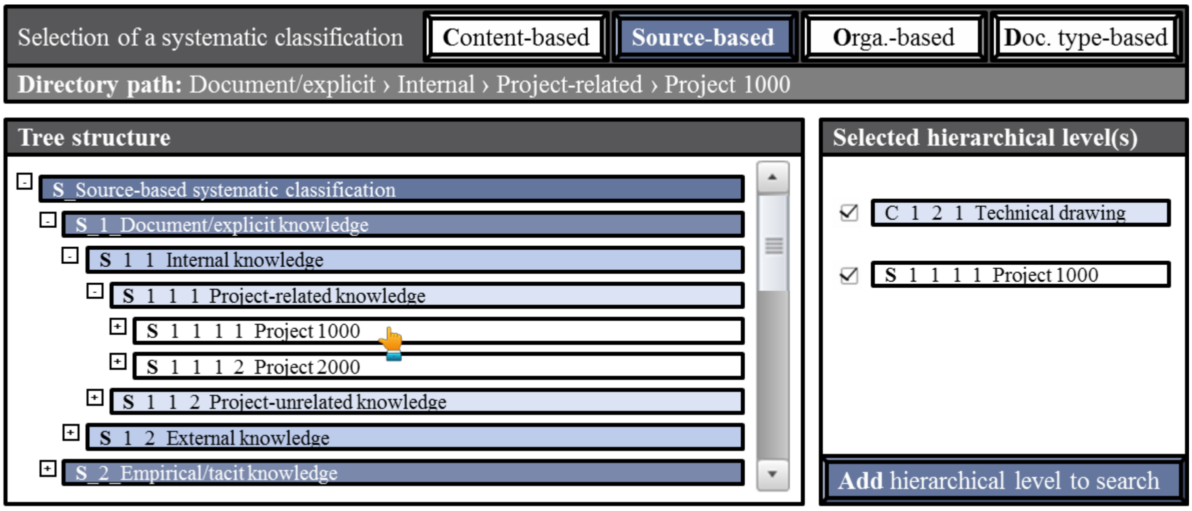

Figure 5 Significantly simplified systematic search interface (extract)

Evaluation and discussion

The adopted methodological approach to identify and classify all KaI-Objects of the company from the special engineering industry in order to customise a systematic search interface will be evaluated and critical discussed in this section.

To determine the requirements for a comprehensive knowledge management system from a management oriented view that integrates the currently existing systems, the first step is to analyse the knowledge and information base of the respective company. This is only possible with an appropriate degree of transparency on the knowledge base [9]. As it has been shown in practice, however, an almost total transparency of the internal knowledge base is neither purposeful nor desirable [9]. This was also confirmed in the present industrial case study. Therefore, it was expedient to identify only abstract classes of knowledge and information (KaI-Objects) and not every "single piece of knowledge or information". It was also reasonable to classify the KaI-Objects according to the habits of employees (e.g. content and source-based), as this will ensure their acceptance. Nevertheless, the numerous evaluation workshops have shown that a precise classification of the KaI-Objects which all employees agree on is very difficult to realise. To avoid the iterations in the development of classification schemes as far as possible, it makes sense to work together with an interdisciplinary team consisting of three to five experienced knowledge engineers of the company in order to make some drafts of a maximum of four different classification schemes.

To develop an intuitive search interface initially all potential users from different departments were interviewed about their needs and ideas. By the early involvement of employees, it was possible to ensure that the developed user interface of the search mask will meet the requirements of the prospective users. Moreover, the created mock-up made it possible to visualize the various search functions with their respective advantages. This mock-up also served as a basis for discussion and inspiration in later discussions. As a consequence it was possible to develop among others an exactly to the requirements of the employees' adapted (combined) systematic search interface. In conclusion this methodological approach allows taking into account all the requirements for a company-specific classification of the knowledge base as well as an intuitive systematic search interface from a management and supply oriented view.

Conclusion and future work

Based on the fundamentals and related approaches about 400 KaI-Objects were identified and subsequently classified in order to be able to create a concept for both a computer-based (management oriented view) and user-friendly (supply oriented view) knowledge management system using the example of an industrial company. The evaluation of the systematic classification as well as the systematic search interface by the potential users of the knowledge management system was all in all positive.

Future work should first of all focus on further cost-benefit analysis. With regard to the management view it is important to determine, among other things, how much disk space a systematic classification (e.g. by reducing redundant data) can be saved. In addition, the conduction of reliable tests with the systematic search interface is necessary to verify the expected significantly reduced search time for retrieving knowledge and information. These two benefits would lead both to lower IT costs and lower labor costs. These cost savings have to be set in relationship to the costs incurred by the introduction and implementation of a company-specific knowledge management system.

In a second step, the evaluation of existing knowledge management solutions regarding the requirements from the user requirement specification has to be carried out. This requires not only the analysis of the IT systems that are already in use by the company but also the evaluation of available knowledge management systems on the market.

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