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THE ECODESIGN KNOWLEDGE SYSTEM – SUPPORTING ECODESIGN EDUCATION AS WELL AS ECODESIGN KNOWLEDGE MANAGEMENT

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1. Introduction

Design is an information intensive process. Obviously, the information needs even increase when new aspects such as environmental requirements are introduced into the design process. In that case, two major needs can be distinguished:

- ***ecodesign education***: providing easy access to domain knowledge from the environmental domain, which is usually outside a company's core business;
- ***ecodesign knowledge management***: providing a platform for sharing experience, thus allowing both a more easy transformation of (individual) project knowledge into (common) organisational knowledge and a more easy access to company wide organisational knowledge;

Currently, ecodesign education and knowledge management is mainly limited to the mere supply of ecodesign handbooks, guideline lists and off-line courses. However, designers stress that the handbooks mostly end up in a lost corner of a faraway shelf, since the time for retrieving information is too high. Moreover, little time is available for off-line education. Consequently, a flexible system was developed able at providing situation-dependent ecodesign knowledge: the Ecodesign Knowledge System [Dewulf 2003]. It contains a large variety of knowledge items, including guidelines, experience, themes, standards and legislation, and term definitions. By definition, all knowledge entries of the Ecodesign Knowledge System are referred to as "documents".

2. A bird eye's view on the Ecodesign Knowledge System

A first task of the Ecodesign Knowledge System is to allow for *retrieval* of documents. Consequently, a database is provided, storing for each document an ID number, the document title, a short abstract and the address where the full document can be found. A second task is to allow for *efficient retrieval*. To this aim, the Ecodesign Knowledge System utilises four strategies:

- *Classifying information items in a number of document types,* such as guidelines, experience, themes, standards and legislation, and term definitions;
- *A conceptual and contextual indexing technique*, used to classify not only the available ecodesign knowledge but also the user (retrieval) situation according to flexible classification schemes for three conceptual domains (See Section 3);
- Structuring *documents into a web of knowledge* by making explicit the intrinsic links between documents (See Section 4);
- *Direct access to term definitions* when selecting an unknown term in an Ecodesign Knowledge System document.

The first three strategies are realised by means of an appropriate relational database structure. The latter strategy is realised on the level of the functional software layer.

3. Contextual indexing

Simple knowledge retrieval based on finding search terms in documents (such as for internet searches) has a number of drawbacks. While synonymy – i.e. concepts being denoted by different words – causes queries to miss relevant documents (referred to as bad 'recall'), polysemy – i.e. words denoting different concepts – causes queries to hit irrelevant documents (referred to as bad 'precision'). As a solution to this problem, knowledge management solutions make use of classification schemes, defined as a finite range of pre-determined, defined logical values (or meanings, or descriptions), that may be assigned to a conceptual or physical item [OIT, 2002]. IT solutions allow quite complex conceptualisations and ontologies to be the basis of multi-dimensional classification schemes, organised in a network instead of in a pure hierarchy of classes.

A number of ontologies, conceptualising the design process, the design problems, and the design support tools, have been developed in the field of design science and knowledge management for design support (e.g. [Ullman 1988], [Kuffner, 1991], [Baya, 1996], [Özgur 1999]).

Many of these ontologies have, however, been developed in view of developing far-reaching knowledge management applications, able of capturing not only knowledge from design results, but also from the reasoning of the designers in working towards the achieved results. Since the Ecodesign Knowledge System is dedicated towards a specific application, i.e. ecodesign support, some elements from the above ontologies can be omitted, while others can be made more concrete. Therefore, a dedicated classification scheme was developed. The scheme comprises three dimensions, which represent respectively the product (what type of artifact is the user designing?), the requirements (what environmental requirements have been imposed?), and the design process (what stage of the design process is the user in?). Mapping both the actual user situation as well as the available knowledge items on these conceptual domains defines what documents should be shown to the user (Figure 1).

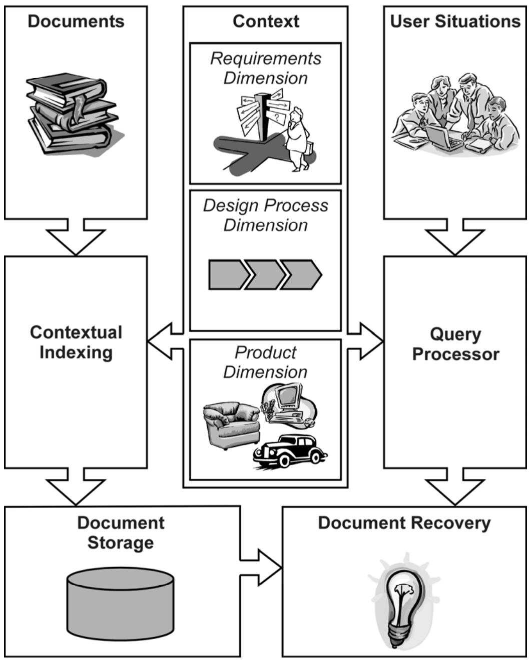

Figure 1. Contextual indexing principle of the Ecodesign Knowledge System

The following sections first introduce document classification according to each of the three dimensions separately. While the basic ideas of the Ecodesign Knowledge System can thus be explained and exemplified, evidence will show that document classification according to the separate dimensions is insufficient. Subsequently, Section 3.4 will explain how the three dimensions are combined in order to create user contexts as a basis for the classification of knowledge and retrieval situation.

3.1 The design process dimension

The use potential of information varies throughout the design process. However, most current tools fail to make this distinction and merely provide a list of, e.g., recommended design rules with little direction on when and how they should be used. Therefore, the first context dimension model allows categorising information according to the different types of design activities commonly performed by designers (Figure 2). A number of remarks can be made:

- The design dimension concepts are derived from the Theory of Technical Systems by [Hubka 1988], and from the general phase method for design by [Pahl 1996]. Hubka identifies elementary design properties such as material and shape as the basic design decisions influencing all observable properties of a technical object. Together with the selection of the working principle of the product, these elementary design properties describe, on a micro scale, the activities of a designer. Due to the specific function of joints in view of the important ecodesign focus 'disassemblability', the selection of joints have been added in comparison to the model by Hubka. On a macro scale, design activities are represented as a series of phases (e.g. conceptual design);
- A hierarchy within the design process dimension model is constructed between the 'macro' phase models and the micro 'elementary design activities'. The applicability of information items is inherited throughout the hierarchy;
- A drawback of the current classification is the fact that 'component selection' - typically a part of embodiment design - is not present as a design activity: it is regarded as a small scale design process, in which all phases and tasks of a design process need to be performed;
- Note that the design process dimension can not only be used to supply ecodesign knowledge in terms of changing product concepts and attributes, but also to supply guidance on what procedures to follow. For example, linking the guideline 'perform an LCA on the previous generation product' to the target setting concept would steer the ecodesign process in the direction of current state-of-the-art ecodesign pilot project procedures.

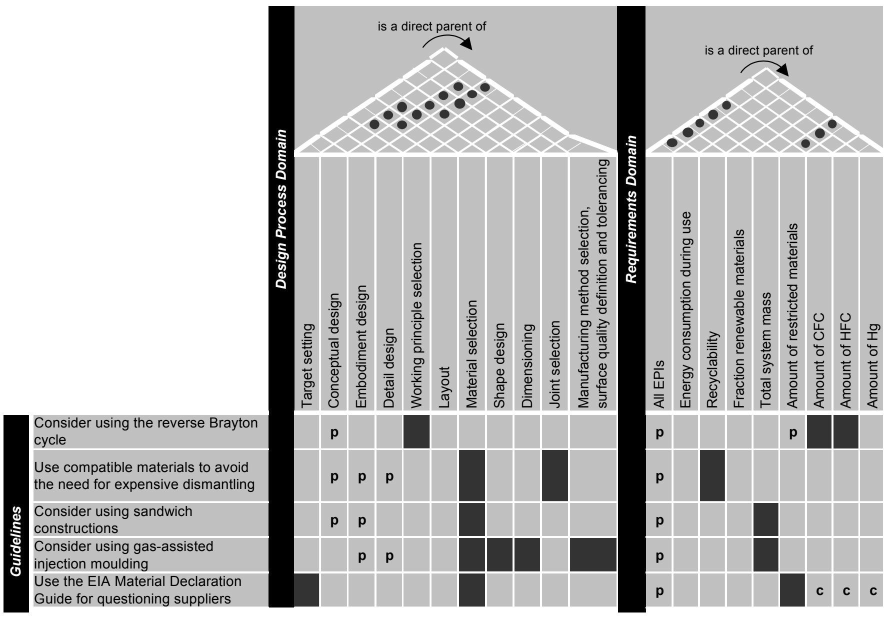

Figure 2. Selection of documents classified according to concepts of the design process dimension and of the requirements dimension. A dark field represents an applicability stored in the database. 'c' and 'p' respectively represent applicabilities which are not stored in the database, but which are inherited as respectively child or parent of an applicable design task or EPI

3.2 The Requirements Dimension

The second dimension of the classification scheme covers the imposed requirements, which are obviously decisive for the user situation. For the Ecodesign Knowledge System, the environmental requirements are expressed in terms of product-oriented Environmental Performance Indicators (EPIs) [Granholm-Thorén 2001] (See Figure 2).

3.3 The Product Dimension

Finally, documents are classified according to a product dimension (not depicted in Figure 2), which covers a characterisation of the type of product for which the document can provide useful input. Concepts of this dimension can be found on a functional level (e.g. cooling, fire extinguishing, or transportation), on a machine organ level (e.g. structural parts, mechanical parts, or electronic parts), and on a material level (e.g. metals, polymers, or ceramic materials). Between the concepts of this dimension, a hierarchy is again created (See [Dewulf 2003]). Company specific concepts can be added to the existing product model in order to tailor the system's categorisation possibilities to the needs of the individual enterprise.

Finally, the external conditions are added as a separate level of the product dimension. External condition concepts allow to take into account the particularities of a product being used under specific circumstances. For example, a structural part mounted on a rail vehicle will primarily need to be a lightweight construction, while optimal recyclability might be more important in other circumstances

3.4 From Concepts to Contexts

The simple hierarchies of concepts for the three dimensions (product, design process and requirements) allow for classifying a large part of the ecodesign knowledge. However, proper classification according to the individual dimensions is often insufficient. For example, the guideline "consider using composite structures" always supports reducing the EPI score 'total mass', but only supports reducing the EPI 'total energy consumption during use' in case the structure is mounted on a moving object (which is a product characteristic). Similarly, it is obvious that the applicability of the guideline "consider using the reverse Brayton cycle" to the design process concept "working principle selection" only counts if combined with the product concept "cooling system" and either or both the requirements concepts "Total mass" and "Amount of restricted materials". Therefore, the Ecodesign Knowledge System introduces a 'use context' as a combination of concepts from the three dimensions.

Contexts can be structured in hierarchies similar to the concept hierarchies. Moreover, it can easily be understood that the context hierarchy inherits the concept hierarchies: combining each of two hierarchically related concepts with given concepts from the other dimensions will lead to hierarchically related contexts. This property allows a more simplified maintenance of the hierarchies in the database underlying the Ecodesign Knowledge System.

3.5 Knowledge Retrieval

When retrieving documents from the repository, queries are formulated using concepts from the same domain models, which are again combined using various logical operators. A query results in all documents linked to the given context as well as to any of the parent contexts straight up the context hierarchy. Moreover, the user can be informed that information is available for more specific contexts (i.e. the child contexts).

4. Creating a Web of Knowledge

Whereas the conceptual and contextual indexing presented in the previous sections are primarily oriented towards document selection, the creation of a web of knowledge is aimed at making explicit connections between documents. For example, a designer of HVAC systems confronted with the guideline "avoid the use of halogenated substances" is probably interested in more specific guidance on possible alternatives, such as provided by the guideline "Consider using technology based on the reverse Brayton cycle". Moreover, he is probably eager to learn about previous applications this technology (experience). Undoubtedly, reference to and commentaries on existing and pending legislation with respect to the phase-out of some halogenated substances will clarify the guideline (standards and legislation). Finally, he might be interested to learn about the potential impact of halogenated substances on the environment in order to understand the reasons why they should be avoided (theme).

In practice, it would however prove to be impossible to make explicit connections between the thousands of documents available in a well-developed knowledge system. Fortunately, this is also not required, since related documents will often be linked to similar applicability contexts. In some cases, however, the similarity of contextual indexing is insufficient and defining explicit inter-document relations is advisable.
In particular, it is appropriate to link experience to the guidelines exemplified or applied in the particular situation described. Another particular application is the creation of a hierarchy of guidelines. In a complex user situation, it is well possible that, after the selection process using contextual indexing, some tens of guidelines still remain which mutually differ with respect to their level of specificity. Some of them are rather generic, while others are more specific descriptions of how a more generic guideline can be applied. For example, the more generic 'parent' guideline 'Reduce energy consumption during use' can be applied in different ways, such as by following three major ‘child’ strategies: 'Reduce energy demand', 'Reduce energy losses', and ‘Recuperate energy losses’. Each of these strategies can, in turn, be broken down into more specific guidelines. The guidelines found at the top of the hierarchy are directly linked to the EPIs defining the environmental dimension.
The hierarchy of guidelines which is thus created allows the Ecodesign Knowledge System user to screen the available guidelines in a structured way. Using a presentation format similar to the MS Windows Explorer environment, the user is first confronted with the high level strategies, and can subsequently decide for which strategy he desires more detailed guidance (Figure 3).

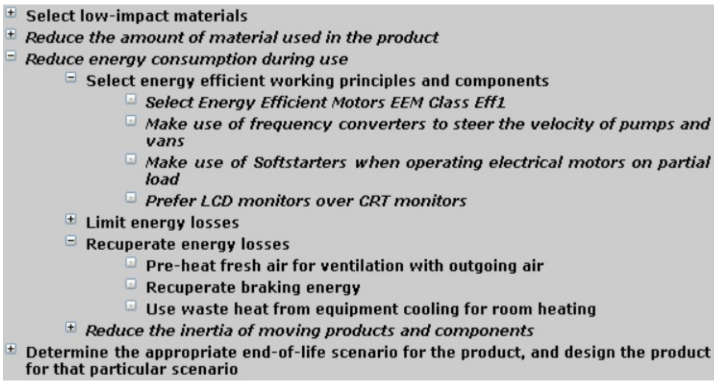

Figure 3. Using the hierarchy of guidelines for structuring the information flow towards the user

Note that a logical connection exists between the hierarchy of guidelines presented in this section and the hierarchy of applicability contexts: the applicability context of a guideline is a sub-set of the union of applicability contexts of its parent guidelines. Consequently, adding a new guideline inside an existing guideline tree facilitates the definition of its applicability context. Vice versa, querying the database based on a known applicability context of a new guideline allows for retrieving potential parents in order to position the new guideline inside the guideline hierarchy.

5. Application horizons

The quality of the feedback gained from the system is to a large extent dependent on the contents of the Ecodesign Knowledge System database. This covers both the amount and the quality of the information in the database, as well as the thoroughness with which the contextual indexing and the construction of the web of knowledge were performed. It is consequently obvious that the investments needed to develop an initial Ecodesign Knowledge System is relatively high. However, once an Ecodesign Knowledge System has been built, it is very flexibly adaptable to a wide range of companies in view of its ecodesign educational aim: classifying the type of products designed by the company according to the product dimension of the applicability context suffices, while further advantages of the system can be reached by also tailoring the other dimensions of the applicability context scheme to the POEMS of the company.
It must, however, be recognised that the costs for system maintenance are relatively high when using the proposed system as a dynamic ecodesign knowledge management tool. As denoted by [Troxler

2002], knowledge management not only covers knowledge dissemination and utilisation, but also knowledge identification, creation, capture, and maintenance. The system would be beneficial as an ecodesign knowledge management system in companies that organise the ecodesign support process around a centralised ecodesign competence centre, as is common today. Consequently, these competence centres are presumed to bear full responsibility with respect to knowledge identification, creation, capture, and maintenance as well as with respect to quality assurance. Their time investment should be weighed against the time gain on the designers' side if appropriate information can be found in a more efficient way.

6. Conclusions

This paper presented an Ecodesign Knowledge System, aimed at supporting hands-on ecodesign education as well as ecodesign knowledge management. The system makes use of four strategies to support the efficient retrieval of stored documents: a classification in a number of knowledge types, a contextual indexing technique, a web of knowledge, and direct access to term definitions.

A preliminary implementation has received very positive reactions from designers during demonstration sessions. However, a major disadvantage of the system is the very high manpower requirement for setting up and maintaining such a system. Therefore, construction and continual updating of a company specific ecodesign knowledge system in view of knowledge management will only be suitable for large enterprises with a centralised ecodesign competence centre. SMEs can take advantage of an externally supplied ecodesign knowledge system, which then mainly serves the purpose of ecodesign education and technology watch, rather than being a company specific ecodesign knowledge management system.

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