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AN EXPLORER STYLE INTERFACE FOR DESIGN KNOWLEDGE INDEXING BASED ON TAXONOMIES

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ABSTRACT

The designers often find existing knowledge management systems being too complicated and/or too obtrusive to be used in their everyday practice. This paper explores the proposition that a simple and intuitive interface combined with simple and easy to use methods of indexing and searching design knowledge might overcome those problems. A prototype software tool in a form of "explorer style interface" for knowledge indexing has been developed, together with the proposal of relational database structure for storing and searching of indexed knowledge. Knowledge indexing method is based on taxonomies – both generic and specific. Elements (nodes) of taxonomies are visualized as folders and file structures – this approach enables very simple method for their creation and maintenance and also enables very simple and natural access to design documents and their fragments. We have also investigated how some predefined elements for generating parts of design rationale explanations could be introduced in order to speed up the knowledge capture and indexing processes.

Keywords: design knowledge indexing, taxonomies, interface, knowledge management

1 INTRODUCTION

Adding knowledge to existing knowledge base requires a high level of expert human intervention [1]. The knowledge reuse is often ad-hoc and the designers often consider the time and effort needed to locate the information and investigate information usefulness as too costly, often resulting in little or no attempt at reuse [1]. The consequence is that designers are often sceptical about the purpose and usefulness of knowledge capture and indexing too. In the design environments that have little or no experience with knowledge management systems, designers often find those processes too obtrusive and time consuming, with small benefits for them.
The aim of this research is to explore the possibilities of making the processes of knowledge indexing (while capturing) and knowledge search (while reusing) as simple and "comfortable" as possible.

The research questions that will be considered in this paper are:

- how to implement problem specific, actual elements for knowledge indexing (notions from everyday use at lowest levels in design taxonomies) that will be easier to use for designers in contrast to abstract notions (from top levels of design taxonomies)
- is it possible and useful to implement predefined elements and structures for generating parts of design rationale explanations, e.g. like sets of "pro" and "con" arguments for narrow domains specific in particular design environments (the purpose of these sets would be to ease and speed up the capture and indexing processes)
- could such an approach encourage designers to capture and reuse more design information and knowledge than they would "normally" do in their usual design routine

This paper explores the proposition that a simple and intuitive interface combined with "easy to use" methods of indexing and searching might lead to a system that will be "efficient enough" and especially "comfortable enough" for practical usage in small and medium enterprises.
To demonstrate this idea a prototype software tool in a form of interface for knowledge indexing has been developed, together with the proposal of relational database structure for storing and searching of indexed knowledge records. "Knowledge record" is here considered as data structure that include a set of links to information objects and/or their fragments, coupled with textual explanation(s) of design rationale, being connected in particular context. Knowledge record is recorded in database together

with associated set of tags (indices) (figure 1). Set of tags should provide precise knowledge retrieval of relevant knowledge records in the process of design knowledge reuse. In the proposed approach each tag corresponds to one node in one particular design taxonomy. It is assumed that a set of several taxonomies for a set of different contexts (or points of views) will be used.

The main objectives are:

- to develop simple, but precise enough indexing system that will encourage designers to capture and reuse design information and knowledge;
- to identify and propose appropriate paths of "navigated" (suggested) knowledge indexing and retrieval (search), by usage of predefined elements, that will shorten the time spent for knowledge indexing and capturing;
- to enable the users (designers) to develop and use their own indexing taxonomies for their particular contexts and domains in simple and intuitive manner.

The scope of this research is the improvement of knowledge management process for embodiment and detail design tasks that are parts of complex and long-lasting product development projects which repeat in cycles of 3-5 years. In other words, the research focus is on knowledge management for repetitive (redesign) tasks.

1.1 Related works

Ahmed et al. tried to identify concepts of the taxonomies required for indexing design knowledge [2,3,4]. This research identifies two main advantages in having a visible indexing structure: (1) to assist designers in focusing their query through browsing or navigating and indexing structure; and (2) to overcome difficulties in search engines not understanding the context of a query. Ahmed proposed the method consisting four taxonomies named as Engineering Design Integrated Taxonomy (EDIT) which have been integrated and implemented in software named CITED (Cambridge Integrated Taxonomy for Engineering Design).

Kim et al., [1] have involved the dynamic nature of the design process by observing design activities for identifying the current design task. They developed the software prototype to demonstrate the approach which actively recommends the information that a designer might need to be aware of when carrying out a given design task. Design Rationale editor (DRed) has been used as a tool for exploring problems and finding solutions. Consisting of three interfaces (1) User Profile; (2) Search; and (3) Presentation, the approach monitors the elements being created by designer and uses this monitored information to recommend the rationales that are deemed useful.

DRed is a graphical software tool for design rationale capture principally in the early stages of design and in resolving in-service problems. It has been found to help designers view, clarify and structure their design thinking, assist with managing design tasks and capture design rationales as they are created. But in embodiment and detailed design activities DRed has not yet achieved significant use in industry. Bracewell et al., [5] have explored how the new extension, implemented with MS Excel, MS OneNote 2007 and Autodesk Inventor might be used to capture embodiment design, enabling the collaborative annotation of many types of non-DRed design documents by means of the creation of bidirectional hyperlinks between locations in these documents and DRed elements

2 DESCRIPTION OF THE PROPOSED METHOD AND TOOL

The main concepts and ideas that emphasize the simplicity and "user friendliness" of the proposed software tool are based on the following reasoning:

- designer must be able to easily create and manipulate its' own taxonomies that are being organized as hierarchies of folders – as any other folder structure in PC OS file management system
- methods for visualization and manipulation of the taxonomy structure has to be known and familiar to everyday procedure like for instance working with any usual file management tool
- identical interface and taxonomies should be used both for indexing and for searching the knowledge records
- the time needed for recording (capturing) new knowledge must be shorten as much as possible - therefore sets of "predefined" data structures (valid in narrow domains) should be introduced to enable semi-automatic generation of parts of knowledge recordings

The global scheme of proposed ideas and concepts for knowledge and information indexing is shown on figure 1.

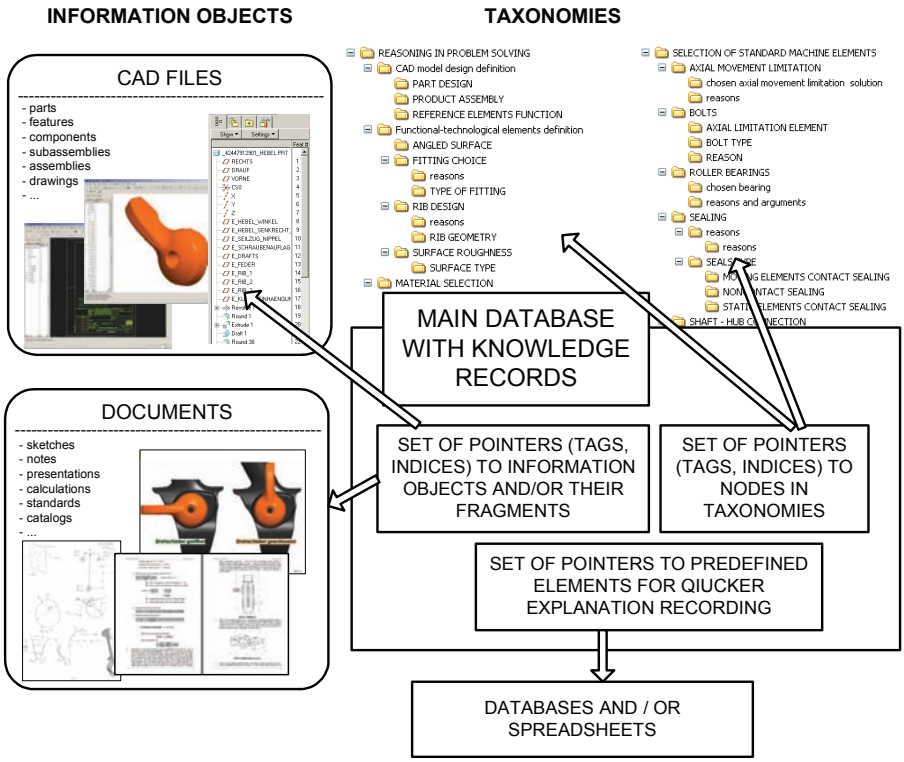

Figure 1. The structure of proposed concept for knowledge indexing

2.1 Overall usage scenario

Proposed usage scenario includes following steps: (1) initial creation of taxonomies that will be used for indexing, (2) knowledge capture process in which knowledge records will be indexed and associated with sets of information objects, (3) knowledge retrieval process – search for previously indexed records.

Initial creation of taxonomies: The taxonomies for particular design contexts have to be created as hierarchies of folders, using file management tool. These folders represent taxonomy nodes. After initial creation of taxonomies, the designer has to start the database procedure that will perform following tasks: checking the consistency and mapping of taxonomies data and structure to database tables. Node names (actually folder names) will be written in corresponding tables, and each node will be associated with unique tag.

Indexing the knowledge record: each "chunk" of knowledge and/or information that is being captured will be stored in database as a structure consisting of several parts in various database tables. This structure will be named "knowledge record" in further text. The main part of knowledge record is a set of associated indices (tags). The designer associates the set of tags to knowledge record simply by marking the check boxes beside appropriate taxonomy nodes (figure 2). In the process of selecting the appropriate nodes to be used as indices, the taxonomies could be shown and manipulated independently from each other. In other words, only one particular taxonomy for particular context could be shown, expanded and explored, and then collapsed or deleted while working on another one. This is enabled using the Visual Basic "Tree view" control that behaves equally as the interface of

"Windows explorer". When the designer selects all the desired indices, he/she should start the procedure for storing the generated structure in the database.

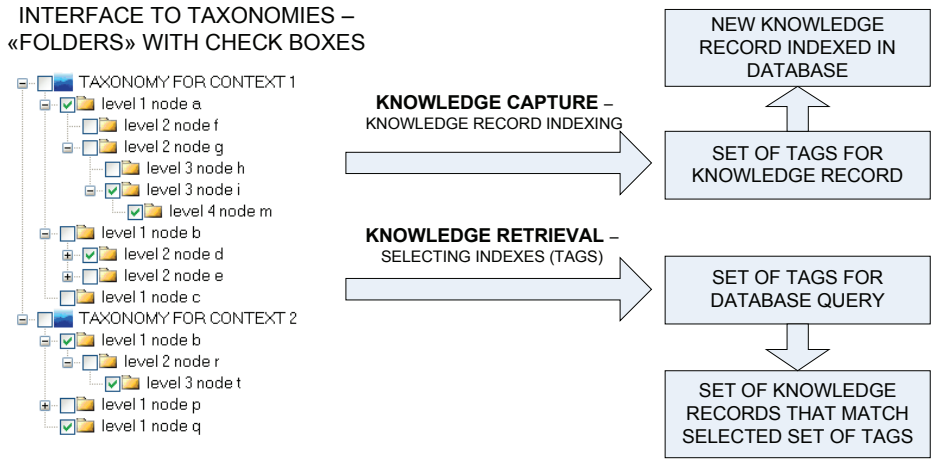

Figure 2. Using the proposed interface for indexing or searching

Associating information objects: each knowledge record could be linked with a set of "information objects" and/or their fragments. The same procedure as described previously for knowledge record indexing is here valid for associating files of any kind to knowledge record being captured. The only difference is that the folder structure is now a "real" folder structure from local hard disk or network server – not the one that plays the role of visualizing taxonomy. Additionally, a special kind of links could be established to fragments of particular documents – this issue (feature) will be explained later in chapter 2.3.

Knowledge retrieval – search for relevant knowledge records: we argue that the main advantage of the proposed approach is the use of same interface, taxonomies and methodology for searching as were previously described for capturing. It is assumed that the designer will be very familiar with the taxonomies that were created for particular narrow domains and contexts in his own environment. Therefore, we argue that the problems of knowledge reuse mentioned before should be decreased with proposed approach. The designer starts the search process by selecting the relevant taxonomies and similarly as in the process of indexing he/she should mark the desired check boxes beside node names (folders) in taxonomy. This process will result with a set of selected tags. The second step is to start the database procedure (query) that will extract the set of knowledge records whose set of tags (indices) match the generated set of tags. The option here is to require complete or partial matching. Depending on search query result, the designer could refine the set of selected tags and repeat the query.
To make the description of proposed tool usage scenario more readable, some concepts and proposals were excluded and will be explained in detail now: *(1) the whole structure of knowledge record, (2) predefined elements for quicker rationale recording and (3) links to document fragments*. Links to document fragments and predefined rationale elements are closely interrelated.

2.2 The structure of knowledge record

Each captured piece of knowledge and/or information is stored in database as new knowledge record. Basic knowledge record data are name and short textual description, the rest of knowledge record contents is structured as collection of categorized "parts" (figure 3). These parts could be links to files of any kind, pointers to document fragments or pointers to some predefined elements like for instance lists of arguments that explains some problem solution. In this paper the research focus is on process of generating and searching set of "tags" or indices associated to each knowledge record. Table "Tags of nodes" contains names of all nodes of all taxonomies. Each "TAG ID" is unique in whole table, while each node name must be unique in the range of each particular taxonomy.

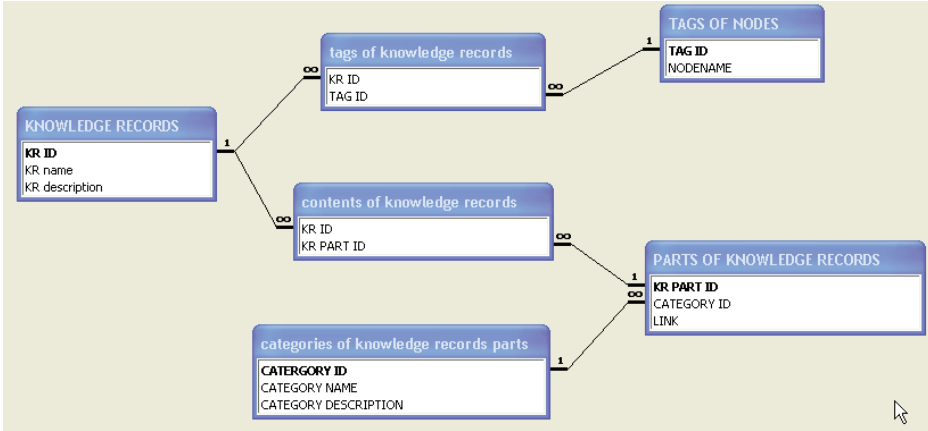

Figure 3. Proposed structure of main database

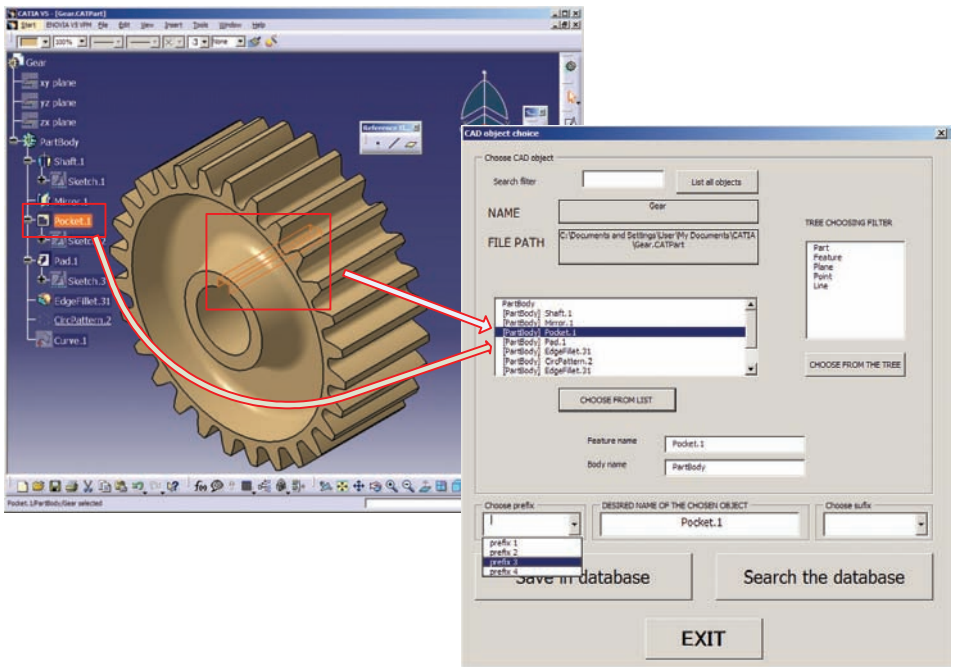

Figure 4. Linking knowledge record to particular feature in CAD model

2.3 Links to selected content within documents

Recent research findings [6] have shown that it is not sufficient to capture only links to whole information objects (files), but that there is a strong need to establish associations with particular fragments of documents. In this project we have started to develop such concept on CAD files. The prototype application [7] has been developed with following basic functions:

- the designer can select the feature and /or product component from the CAD model tree to which the part of knowledge record should be linked (associated);
- the feature name could then be changed (adding prefix or suffix) to indicate that a knowledge record associated to that feature exists;

- when the related feature or product component has been selected, the application will establish the link to it and ask the user to enter the rest of the knowledge record contents.

A part of the described application interface is shown on figure 4. This application has been developed in "Visual Basic for Catia". In further research we will try to develop similar applications based on same principles for other information object categories.

2.4 Predefined elements for knowledge recording and indexing

While interviewing the designers during this and previous research projects some of them suggested us to try the following approach to improve the knowledge capturing process: to prepare a set of predefined data structures and procedures for their management that would be on designer's disposal, in order to shorten the time needed for recording the contents of captured knowledge record. Such an approach should also be targeted to minimize the disruption of the "normal routine" design process caused by the need for knowledge capture and recording. In investigating such approach we assumed that mentioned structures and procedures should (could) be developed for very narrow domains at lowest levels of design taxonomies (presumably (primarily) for notions in leaf nodes). The research project presented in [8] propose an initial set of procedures for knowledge capturing in the form of predefined possible decision explanation sets for specific narrow domains (mainly in the context of explanations of reasoning in processes of machine elements selection). Knowledge base structure is proposed in the form of one "main database" with common record elements and a certain number of individual smaller bases which are specific for each narrow domain. For the purpose of measuring the potentials of proposed approach, we have started to use predefined data sets structured in a form of collections of "pro" and "contra" arguments. Such lists of arguments are valid for particular design environment (office) only, but the main advantage should be in fact that designers are consequently very familiar with them. The following table is an example of partial list of arguments in the decision process of selecting the roller bearing in one particular design office:

ARGUMENTS FOR BEARING SELECTION
assembly and disassembly issues, assembly space required
weight-price-maintenance-duration optimisation
full or partial rotation
temperature differences during pressure mounting
feedback information from assembly line
axial movement limitation required
machining required or not after casting
number and positions of screws in case of a two part housings
sealing requirements
direction of pressure mounting for needle bearings

Table 1. An example of predefined list of arguments for bearing selection

In various design problems, each of above listed arguments could be marked as "pro" or "contra".
Let us now explain the proposition of predefined elements usage according to previously described proposal of "explorer style interface" for knowledge indexing. The main window of the proposed tool (figure 5) contains "tree view" control (for visualizing the taxonomies) and the "list view" control. The "list view" control shows the subelements of the selected node in the "tree view". As nodes in taxonomy are represented with folders, each folder could contain files. These files are shown in "list view" control (figure 5). Being associated to node in particular taxonomy, these files could be used to hold predefined elements for knowledge recording and/or indexing. By clicking the button below the "list view" control, the designer could start the application for opening the selected file. An example could be seen on figure 5: user has checked the taxonomy node "bearing selection procedure" and its subnodes "selected bearing" and "reasons". The "reasons node folder" contains the database file with list of predefined arguments for selection explanation. User then opens the database and by using check boxes on database form, marks the subset of appropriate arguments relevant for current knowledge capture process. The set of marked arguments are treated as tags (indices) associated to the leaf taxonomy nodes. Those tags (indices) will also be included in searching process when a need for

knowledge reuse occurs. We believe that this concept could enable precise and easy to use indexing, but this has to be proven by further testing in design practice.
The similar usage scenario is proposed for establishing links to information object fragments – as described above, the user has to open the file selected in "list view" part of interface. For previously described "Catia" application that means that user will open the desired part or assembly file and then run the application for linking the knowledge with particular feature or product component.

An example of proposed tool usage situation is shown on figure 5. In this example user is in the process of capturing design rationale behind roller bearing selection. Appropriate nodes have been selected and the next step would be to open the database with predefined arguments for generating the design decision explanation. The abbreviation "KR" on figure 5 means "knowledge record".

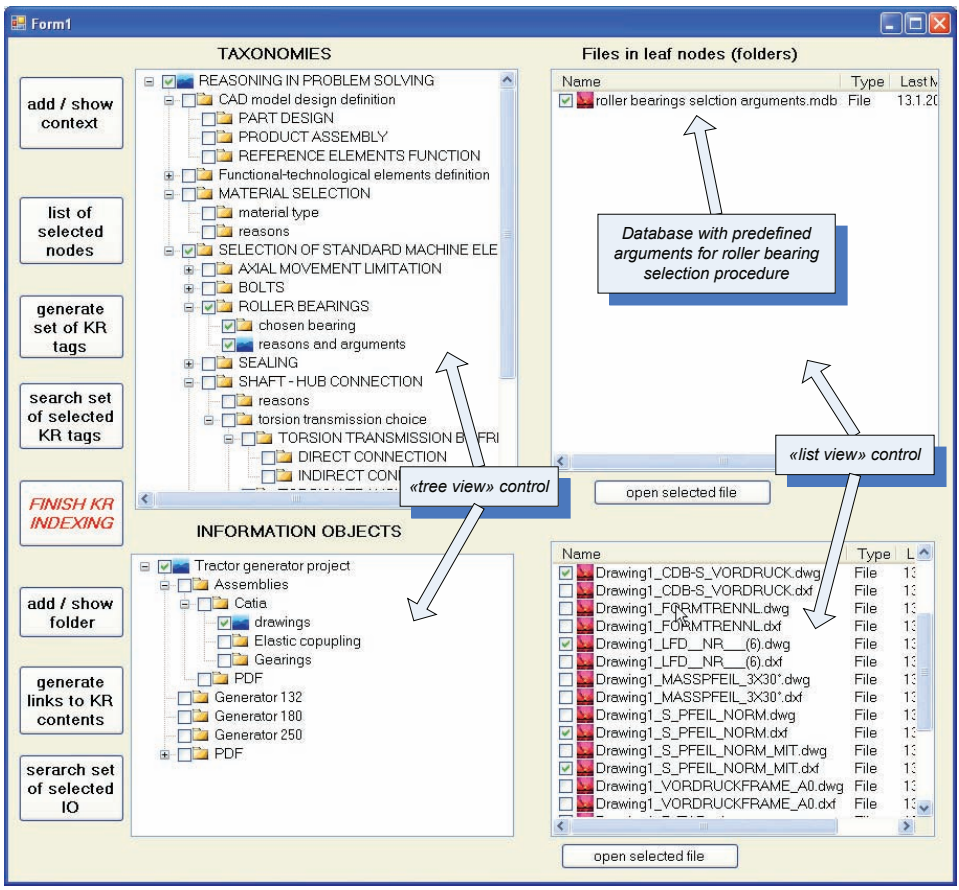

Figure 5. Main form (window) of the proposed tool

3 KNOWLEDGE SEARCH AND TAXONOMY DEVELOPMENT

When a need for knowledge reuse occurs, the search for relevant knowledge records begins with exploring (browsing) the same taxonomy structure that was used for knowledge records' indexing (figure 2, figure 5). The designer has to select (mark) the check boxes near the taxonomy nodes that are relevant for his/her knowledge search. That means that the database has to be searched for all the knowledge records that contain one or more tags (indices) associated with selected taxonomy nodes.
In order to develop proposed taxonomies, an initial research has to be done to characterize the knowledge requests in each particular design environment that tries to implement the tool proposed in this paper. An example of such research could be found in [9]. In this paper we argue that due to

ambiguity of abstract categories developed through examination of engineering knowledge using top-down approach, a different approach towards taxonomy generation should be taken.
We argue for "bottom-up" approach where hierarchy is being built from leaf and/or lower level taxonomy nodes which in fact represent the end solutions - actual or concrete terms that could be easily defined and understood by designers. Nodes on the upper taxonomy levels represent more general or abstract terms – some of them could be structured by grouping lower levels into categories.
Such an approach certainly will result in taxonomies that are different for each design environment, but are best suited for each particular need. However, at higher (more abstract and generic) taxonomy levels there should be a certain number of notions common to broader range of design offices (environments). Interesting considerations on similar issues could be found in [10], where two different approaches to design ontology development are compared.
Some examples of possible knowledge requests that could be answered in proposed knowledge reuse process are:

- Did a similar design problem arise in some of the previous projects, and if, in which one? If such project(s) is found, how the design problem was solved?
- Designer wants to find out more about someone's experience with: one particular approach, one partial solution, etc.
- Which were the main problems in a set of similar previously finished design tasks and projects, what errors have been made?
- What were the reasons of selecting particular design solution in previously stage/project?

3.1 Example of search procedure

Upper part of figure 6 is an example of 3 knowledge records captured in design process of lawn mover. Those records were indexed with different subsets of an example set of 10 indices in the left column. An example of three queries that search all records with different particular indices and their matching sets of knowledge records are shown on lower part of figure 6.

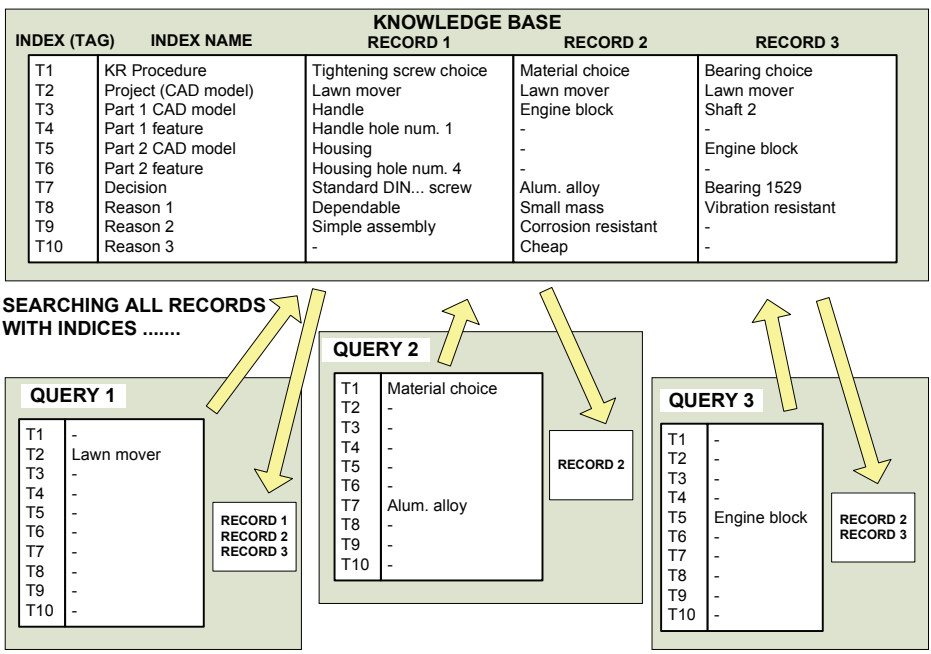

Figure 6. Example of searching indexed knowledge records through various contexts

Due to simplicity of search procedure, all queries could have the same basic structure. To release the designer of unnecessary extra work and education, we plan to develop a special application that will automatically generate database queries with above shown structure, according to user input given

through the "explorer style interface". Let us give the generic example of query structure for searching the set of knowledge records that partially match the tags of selected taxonomy nodes:

```
SELECT [tags of knowledge records].[TAG ID],
[tags of knowledge records].[KR ID]
FROM [tags of knowledge records]
WHERE
((([tags of knowledge records].[TAG ID])="tag1" Or
([tags of knowledge records].[TAG ID])="tag2" Or
…..
…..
 ([tags of knowledge records].[TAG ID])="tag n"));
```

The "WHERE" part of above SQL statement could contain as many "tag clauses" as needed. In the above example table and field names correspond to database structure shown on figure 3.

4 CONCLUSIONS AND FUTURE WORK

The goal of this research was to develop a simple and intuitive interface and methodology for knowledge indexing and reuse based on taxonomies. We argue that such an approach could offer the following advantages:

- A small amount of extra designer efforts for training and implementation
- The proposed system is totally flexible for implementing any number and kind of taxonomies - both generic and specific taxonomies could be combined
- very simple method for creation and maintenance of taxonomies – using OS file management tool - everybody are familiar with "explorer style interface"
- very simple and natural connection to documents file system management

We hope that those advantages could encourage the designers to capture and reuse more information and/or knowledge than in their usual practice.

However there are some issues in maintenance of taxonomies structure that could be sources of problems in practical usage. The connection between database and taxonomy structure is asynchronous – in other words, the taxonomy that is once established should not be changed when the system begins its life in practice. New nodes (folders) could be added without causing any problems, but the existing nodes are not allowed to change their name or position in taxonomy hierarchical structure. In future development it has to be explored whether these problems could be solved by adding new constraints and functionality in software application and proposed methodology.

Future work will be focused to measure the usability and potential benefits of the system. The first precondition for that is the development of initial taxonomies in several different design offices. We will try to start with "bottom – up" approach – from specific to generic. The main challenge in such approach will be to find the common notions (taxonomy nodes) and common design capture patterns as well as common predefined elements for generation of knowledge records contents.

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