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MULTIDIMENSIONAL SYSTEMS OF CONCEPTS – AN APPROACHE FOR A BETTER COMMUNICATION IN THE PROCESS OF REQUIRMENT ACQUISITION

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1. Introduction

Requirement acquisition is one of the most important, but also the most difficult processes in the entire product development. In these phases of the design process fundamental and indicatory strategic choices have to be made, which affect all subsequent steps in the design process. The further the design process proceeds the fewer are the possibilities to change decisions and consequences of mistakes that were made before become more eminent. For these reasons, the early phases of the design process are of special importance and considerable emphasis should be placed on these development phases. This strategy is commonly known as frontloading.
Many errors in the process of requirements acquisition do not arise do not arise out of technical orientated wrong decision or due to a lack of expertise, but because of communication problems between customers and developers or between several developers. Based on the classification of communication problems by Shannon and Weaver [Shannon 1964], combined with the subdivision of semiotics by Morris [Morris 1972], three types of communication failures can be defined: Syntax errors, semantic errors and pragmatic errors. Syntax errors are errors resulting out of the syntactic connections of signs to each other, but independent of the meaning. Primarily faulty transmission and wrong combinations of characters cause these errors. An example for this could be the faulty sending of an e-mail, due to server problems. Because of their technical nature, Syntax errors are not in the focus of this paper.
The term “pragmatic errors” describes errors, which arises due to incorrect relations between sign and interpreter. In a broader sense, this category of errors can be described as errors due to psychological effects. Because of their highly psychological nature, pragmatic errors are not in the focus of this paper. Semantic errors can be divided into three subgroups: synonymy, polysemy and homonymy, which all relate to the core problem “linking of terms and concepts”. Synonymy refers to the condition that several terms denote the same concept. Polysemy expresses that one term illustrates different concepts. Homonymy refers to the situation when nominations are externally similar but the concepts are contextual not equivalent. These semantic errors are in the focus of this paper. With increasing complexity and specialization of the topic, the identification of the semantic error is becoming more difficult as well as the exact distinction and description of terms and concepts.
Possible means for controlling semantic errors are provided by terminology theories in the form of systems of concepts. Especially Thesauri provide such possible means. Systems of concepts are defined in DIN 2331 [DIN 2331 1980]. Systems of concepts visualize the linking between different concepts. It is important to distinguish between the systems of concepts and property networks. In property networks, various properties (represented by terms) are solely connected based on objectively

verifiable, physical relations. Systems of concepts contain connections, which can also be based on highly subjective viewpoints. A system of concepts grows exponentially with each new added term. Even a small system of concepts possesses a high level of complexity. Even with a limitation to terms of the building structure and excludes concepts of connected processes results in a system of concepts too complex to handle without the help of an IT System. It becomes clear that a system of concepts is useless as an effective tool for eliminating communication problems in the requirements acquisition process due to its complexity. Especially because a system of concepts does not include a"guide" how to be used, but needs to be interpreted by the user.

A more advanced tool for the standardization of the communication processes is the conceptual thesauri [DIN 1463 Teil 1 2009]. A thesaurus is a special form of a conceptual system. A thesaurus consists only of terms, which are all synonyms for one concept. All terms are linked to a core term, which is the defined standard nomination for this core concept. With the help of a thesaurus, it is therefore possible to standardize different terms. The greatest weakness of thesauri is that only individual terms are isolated standardized. The relationships between different terms however are not standardized. For a complete standardization in a context, it is necessary to use many thesauri in combination, what makes the process and the system extremely complex. The thesauri are also missing a viable approach to efficiently integrate them into the process of requirements acquisition.

2. Searching for solutions in other disciplines

The aim of this paper is to expand the basic idea of systems of concepts. The complexity of extensive systems of concepts needs to be manageable, the standardization of relationships between concepts should be possible and the approach should be integrated into the process of requirements acquisition through a direct interface.

Due to the large number of concepts and their connections to each other, it is not possible to extract information purposefully by simply looking at the mapped system. The core problem of the high complexity of large systems is a data management problem. A possible tool should allow finding and extracting information from this complex set of data. Since the core of this issue is a problem of datamanagment and therefore a computer science problem, it seems just logical to seek for existing solutions in this area of science. An effective tool for accessing complex data sets is the OLAP data cube. Below the basic principle of the OLAP data cube in his classic manner of use is explained. Based on this, the principle of the data is merged with the approach of systems of concepts and thereby “Term Cubes” are created.

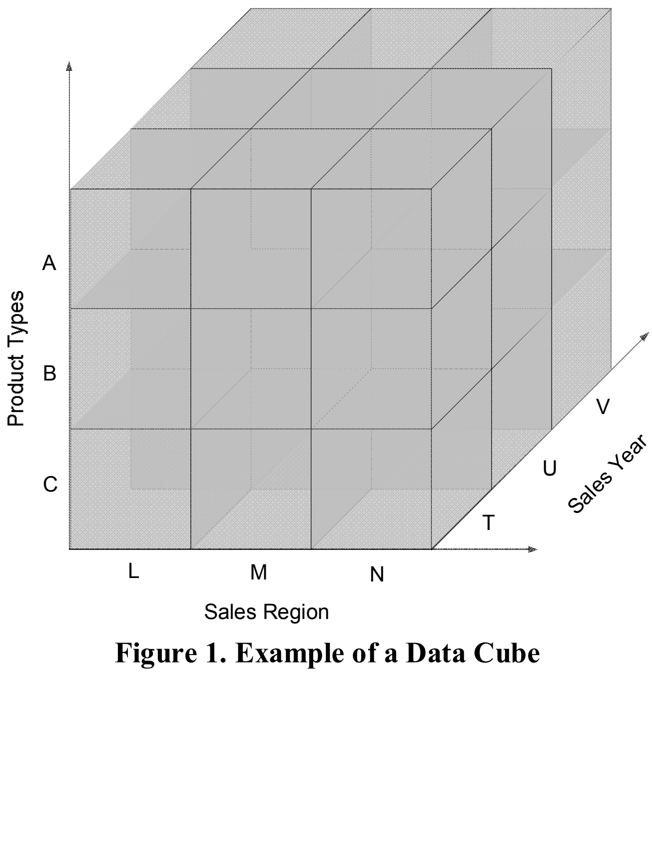

Figure 1. Example of a Data Cube

OLAP stands for Online Analytical Processing and is used in the context of Data Warehouse Systems. The basic idea of the data cube is to select data based on multidimensional search criteria and visualize the selected data. For this purpose, the representation of a three-dimensional cube in a coordinate system is used. The cube represents the total amount of data. The three axes are each representing an attribute dimension of the data. Most commonly, data cubes are used for analysis of sales data. Figure 1 shows a data cube filled with the sales data of a company. The y-axis represents the different types of products; on the x-axis are the different sales regions and the z-axis shows the different sales years. If the user/operator wants information about how many products of type A, in the sales region L, were sold in year T, a smaller data cube is cut out of the large cube. It includes the data fragments, which combine all the relevant attributes. Thus, a multidimensional-intersection is supplied. It should be noted that any quantity of selection dimensions can be used. However, by using more than three dimensions, the visualization by a data cube, is no longer possible. [Codd 1993]
Arising out of the principles of the data cube concept, there are some patterns and functions, which are particularly helpful and often used. These functions are “slicing”, “dicing”, and “drill down (up)”. Represented on a graphical level, “slicing” means that a slice of the data cube is cut off. At the data level, it means that all values of the two dimensions are selected, and for the third dimension, only one or several but not all possible values are selected. Dicing means that for each dimension any number of values can be selected, but never all values of one dimension. Thus, a new, smaller data cube is created. Dicing may also be called a multidimensional slicing. The Drill-down function means, on a graphical level, the subdivision of the cube into smaller cubes. The values of a dimension are split it into their sub values. Changes regarding the level of detail can also be executed into the opposite direction of the scale. This means values of one dimension are put together as a meta value. This process is called drill up. All three functions are shown graphically in Figure 2. [Olap Council 2011]

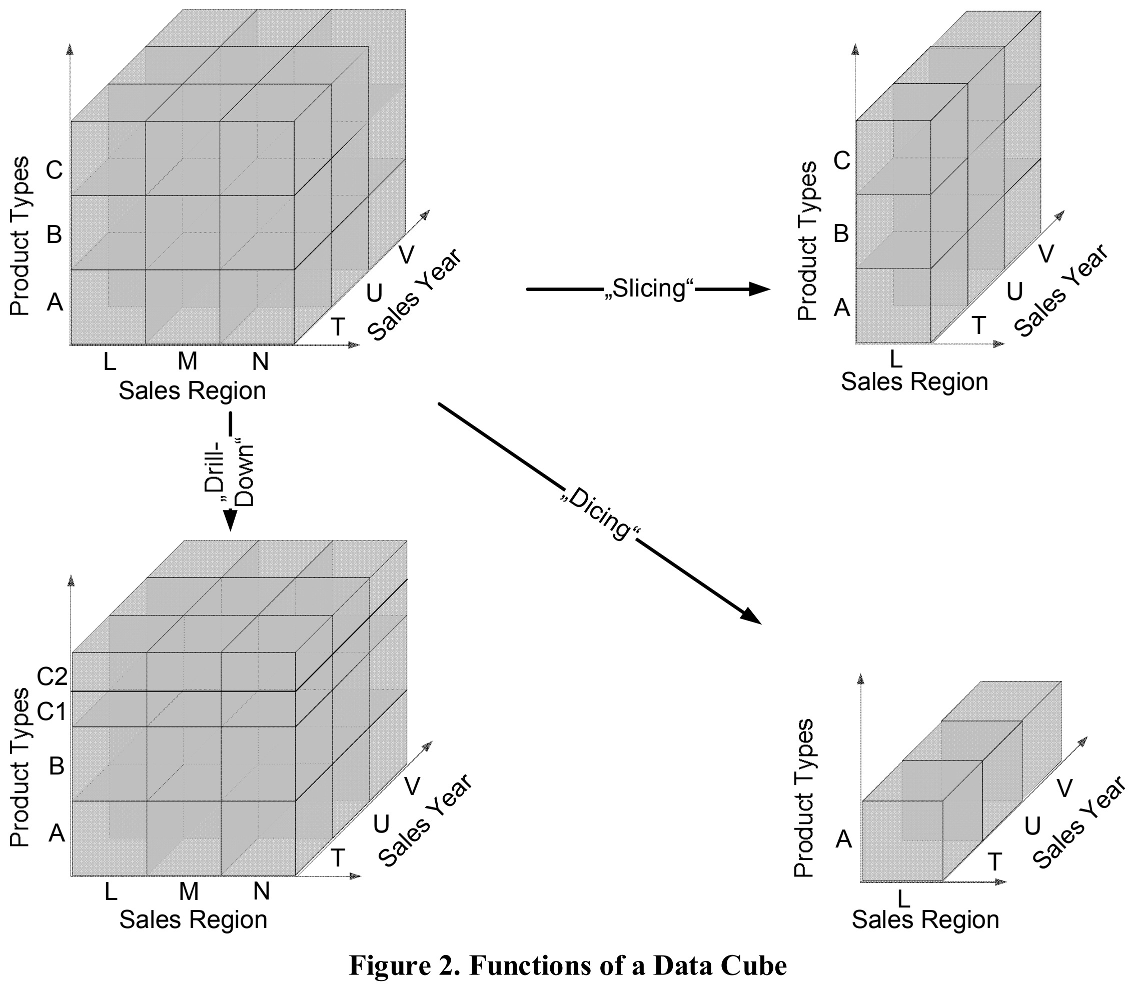

Figure 2. Functions of a Data Cube

3. Applying and expanding an existing solution to the research area

The core idea of this paper is to combine the systematic of systems of concepts with the data management tool of OLAP data cubes. This combination creates a "Term Cubes." The system of concepts is becoming the data to be selected and to be visualized with the Data Cube. The concepts themselves and the connections between them are forming the data together. The axes of the cube are modified as followed: The y-axis is divided by the components of the product to be developed. The selected value of this axis determines the basic element for the search algorithm. All elements resulting out of this search are related to the basic element. By using the Drill-Down/Up function, it is possible to adjust the level of detail of this selection dimension. Thus, components, subassemblies and completed products can be selected as basis element. In contrast to the traditional data cub concept the data of the Term Cube itself is used to divide the dimension. The x-axis is divided using element types. This dimension consists only of two values: “object” and “process”. All concepts can be sorted into one of these two categories. The division of the third dimension is done by the various connection types between concepts to each other. The types of possible connections between concepts are defined by DIN 2330 [DIN 2330 1993]. The principle of such a "Term Cubes" is shown in Figure 3.

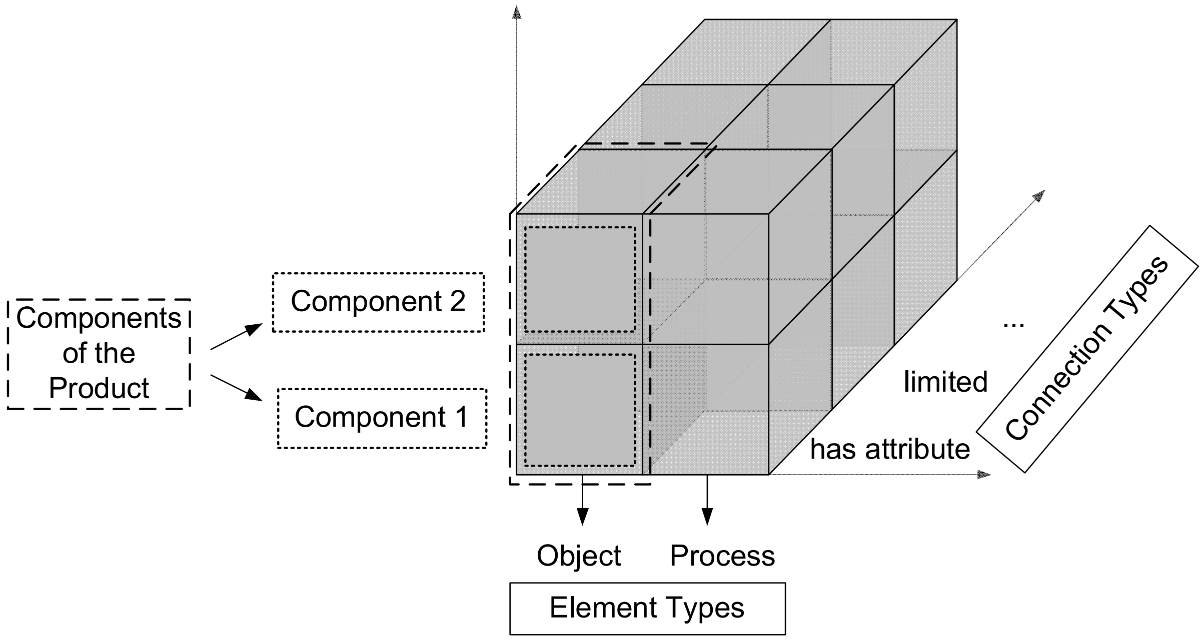

Figure 3. Term Cube

The basic search algorithm of the term cube is shown in Figure 4. As previously described, the selection of a basic element is the first step. The next step is to determine if the elements of the search should be elements of the category object or the category process. Finally, it has to be defined which type/kind of connection should exist between the elements of the result elements and the basic elements. The result of the search algorithm includes a set of all terms, which combines these three criteria. Figure 4 shows an example, which illustrates a search algorithm in combination with a cut-out of a system of concepts:-The value of the first dimension is: “engine”, for the second dimensions it is: “processes”, the value of the third dimension is: “caused by". Through this search algorithm, it is possible to select all concepts, which must be taken into account for a complete requirement acquisition regarding a certain key topic. Thereby the Term Cube application has a similar character to a checklist. However by using predefined concepts and conceptual relationships, a more concrete basis is offered, which does not rely on the associations of the user and thus is clearly more objective than the checklist approach.

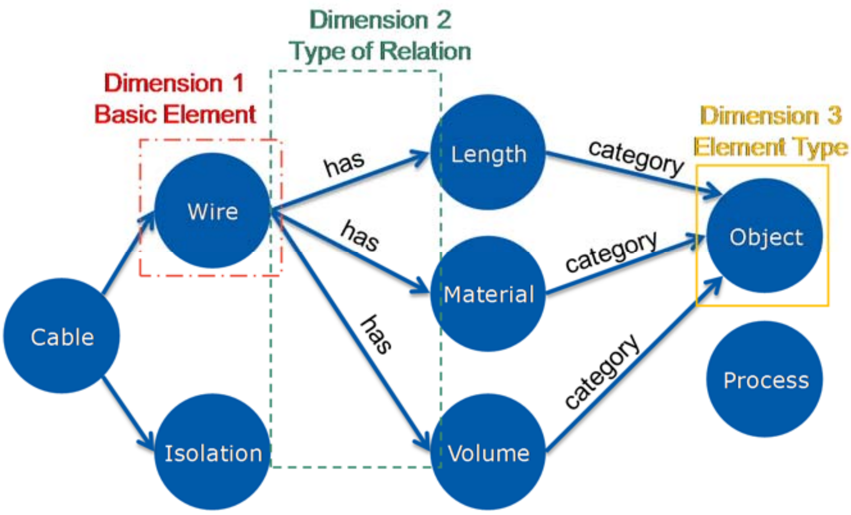

Figure 4. Systematic of the Term Cube Search Algorithm

In a traditional database query, the result would be displayed by a list of all elements fulfilling the intersecting set of all values. Displaying the results with a list like that, would have an antagonistic effect on the basic idea of the Term Cube concept. Information about the relations network of concepts would be lost. The search result should be displayed in a form, which displays and structures the information about concepts and concept relations. To obtain this information, the results of the search algorithm are shown in a centered tree diagram, as shown in Figure 5. [Greiner 1974] This representation could be described as modified shell/orbital model. The Core Term symbols the center of the model and was defined by the first dimension. All connections between the center element and the elements on the first shell were selected by the second search dimension as a connection type. All resulting concepts on the first shell have the type selected by the third dimension. This form of representation can easily be enhanced by adding a second or third shell. The advantage of this representation form is that the information about the concept of connections is not lost and chains of connections are easily visible. This type of representation also allows a dynamic search function, which builds up on the result of previous searches. If the focus of the topic shifts from the core element of the search towards a result element, a new search can be started using the result element as new core element. On the graphical level, this means that the core concept of the representation changes and the shells are re-positioned around the new core term. Using this graphical orientated build up search, it is easy to understand linkages in the system.

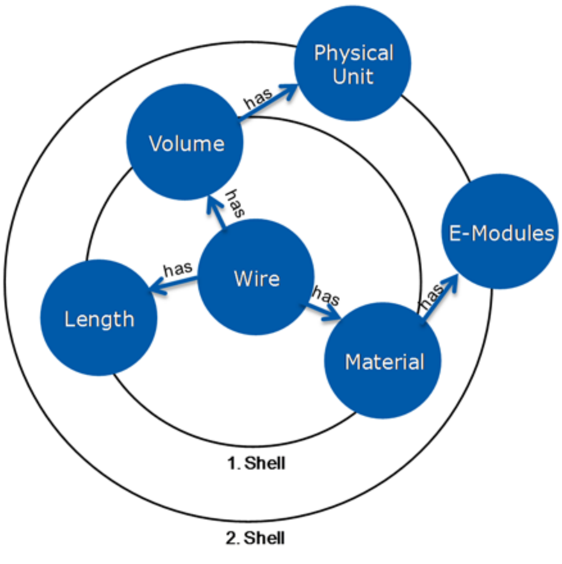

Figure 5. Centered Tree Diagram with Shells

Beyond Terms Cubes offer further opportunities and advanced application possibilities. For example, it is possible to create so called Thesauri Cubes in analogy to Thesauri. The fundamental principle of the Thesauri Cubes is shown in Figure 6. Key element is a standardized system of concepts in which all terms and term relationships are defined as the standard. On the other hand, there are systems of concepts, which are based on the subjective view of concepts and connections by individuals. The acquisition and creation of such individual concept systems is not in the focus of this paper, but is referred to in chapter 5 regarding further research topics. If the same search algorithm is applied to both systems of concepts, the resulting data cubes should be identical. Comparing the two cut out cubes differences concerning used terms and connections should become visible. By highlighting these differences, it is possible to select a relevant section of the system of concepts and standardize it regarding the individual view of an individual. In contrast to the traditional thesauri concept, concepts and their connections are standardized.

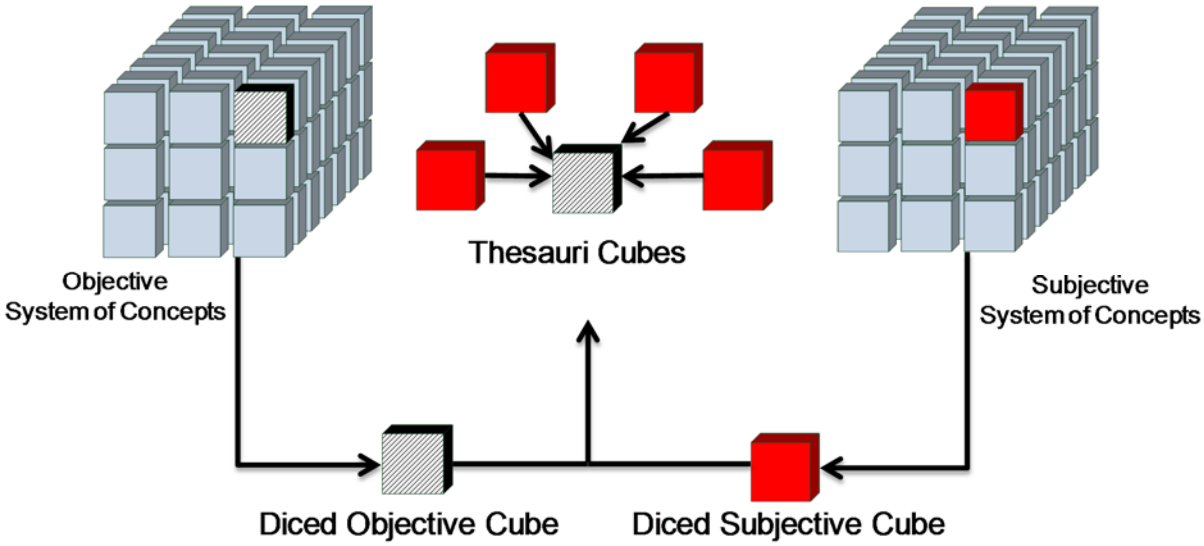

Figure 6. Thesauri Cubes

4. Integrating Term Cubes into the requirement acquisition process

All previously presented applications of the Term Cube concept are applicable to the field of requirements acquisition and provide a possible tool for the optimization of the process. However, the concept is on a highly abstract level and there is still no integration to the process of requirement acquisition. To apply it the interpretative work of the user is needed. The last section of the paper will show how the Term Cube approach can be directly linked to the process of requirement acquisition. As a basis for linking these two processes, the method of "Requirements Clusters" by Roeder et al. is used as a standard for the requirement acquisition process [Röder et al. 2011]. The core idea of this method is explained briefly in the next paragraph.

Clustering requirements is a known method in the field of software development [Al-Otaiby 2005] and design [Maeltz 2007]. Up to now the grouping of requirements is only used as a technique for managing the requirements after their acquisition. Roeder et al uses the idea of clustering requirements as a tool for the phase of requirement acquisition. Clustering requirements in this phase of the design process leads to completely different effects and possibilities.

The idea of the approach is cluster_different requirements under a particular aspect or topic and encode them with a specific term. If the topic and therefore the associated requirements are relevant for the design project, the cluster is enabled. This means all requirements of the cluster are set on the requirement list. This method ensures that all relevant requirements are enlisted if the customer or the developer does not acquire all relevant requirements by themselves; they are still confronted with many not explicit mentioned requirements out of the cluster.

This way it is possible to detect a variety of implicit requirements. Thus, the number of needed iterative back regression is minimized and the number of recognized, implicit requirements is increased. As a result, the required time and caused costs are decreasing with a simultaneous increase of the quality of acquired requirements. A requirement cluster can consist of complete and incomplete requirements. Complete necessities are requirements, which have an attribute and a value. Incomplete necessities have only an attribute. Incomplete requirements are repatriated to the customer after their activation. The Customer has the possibility to define values for them.

There are three approaches how a requirement cluster can be activated and three approaches how to create a requirement clusters. Activation of requirement clusters means that a cluster is considered relevant for the design project and the requirements contained in the cluster are put on the requirement list. The activation process can be triggered by the customer, by the environment or by the product itself. Activation by the customer either is a conscious activation, by the active selection of clusters, or unconsciously, by the analysis of what is said or written by the customer. The activation by environmental factors and by the product itself is both passive activations, meaning that the customer has no direct influence on the activation.

This type of activation ensures that requirements, which are not the focus of the customer and the developer, but are relevant for the project, are acquired. Clusters have thereby also the function of information tanks with stored and structured information. This information of requirements can go far beyond the knowledge of the development team. The creation of requirement clusters can be done subjectively or objectively. The subjective creation is based on the idea that the customer bundles requirements according to his individual mental models and assigns them to a main core topic. These subjectively created clusters represent an effective way to understand the mindset of the customer and help to create an effective communication module.

On the other hand, these clusters are usually not suitable for the requirement acquisition process involving other customers. Only in very few cases, the cluster will have a high enough degree of objectivity, which allows using it for other customers. The objectively created clusters are independent of the person who creates them. These clusters are for example created based on physical laws (property networks) or of public laws. Using the clustering method leads to an increased standardization in the process of requirement acquisition. In addition, iterative loops are reduced and the requirements of certain topics are completely acquired, what results in a reduction of required time and costs.

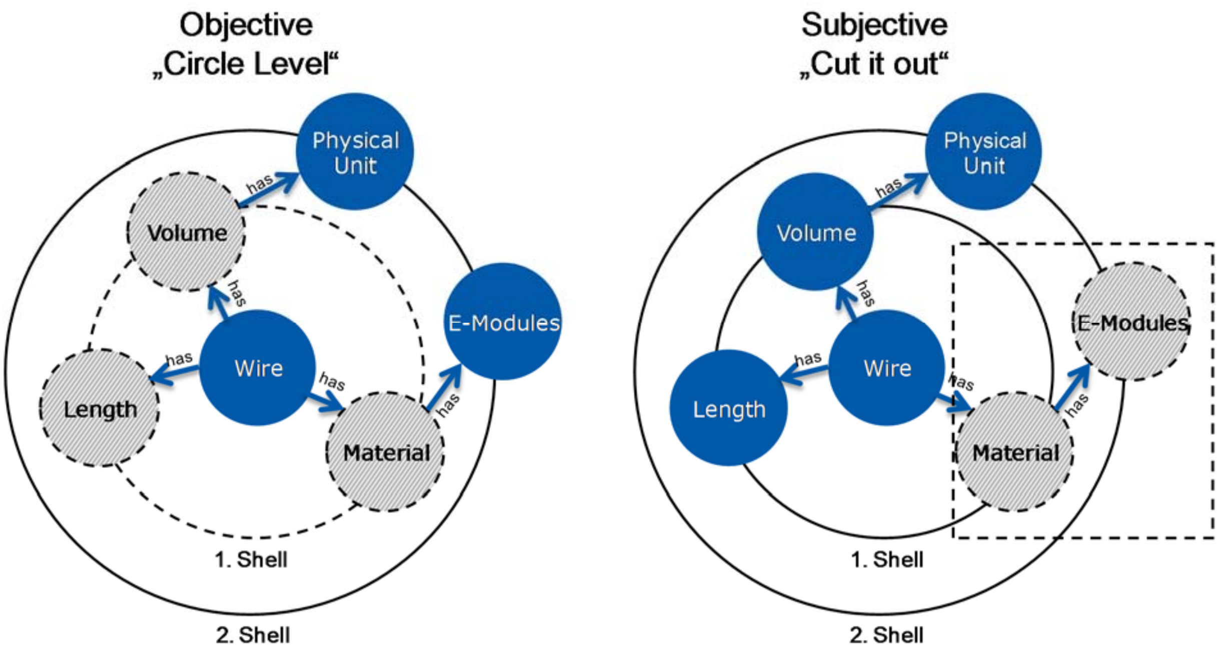

Figure 7. Integrating the approach of term cubes into the process of requirement acquisition

The Term Cube approach can be directly integrated into the cluster approach and thus the term cubes can directly contribute to an optimized requirement acquisition. The initial point for this approach is provided by the representation of the search results as shown in figure 7 and explained in chapter 3. Building up on this graph, the two basic approaches for creating requirement clusters are applied. There are two different approaches for the integration building up on the systematic of the cluster approach: subjective and objective cluster creation. Basis for the objective integration approach are the shells of the representation form. Depending on the purposes of a cluster, it can consist either of elements of the first shell or of elements of any number of subsequent shells. For the subjective cluster approach the customer decides, which elements of the representation form he wants to use. These elements generate a cluster. In the subjective approach, the different shells are not considered as limitating constraints. Using the Term Cube concept to create requirement clusters, Term Cubes can be directly integrated into the process of requirement acquisition. The acquisition of requirements and the standardization of concepts becomes a combined process. As a result, it leads to a higher standardization of the acquired requirements.

5. Reflection

The core idea of this paper is to use the OLAP data cube and combine it with the systematic of systems of concepts to meet the following goals: 1) Selecting information out of a complex system of concepts, which is too large and too complex to overlook 2) Expansion of the core idea of thesauri, so that not only single words but whole sections of a system of concepts can be standardized including the relationships between concepts 3) Possibilities of integrating systems of concepts into the requirement acquisition process for a higher level of standardization.

The usability of the approach is currently evaluated in a case study. Although the results of the case study are not yet on hand, some essential remarks about the approach can be made.

Even for a very restricted topic, the number of terms and connections between terms is quiet large. With every new term, the complexity of the system of concepts grows exponential. Although the approach of Term Cubes provides a method to manage the complexity of system of concepts, there is still the question how the data should be acquired. Not only that the manual acquisition of terms and the definition of connections between them means a lot of effort, but also the objectivity of a manually created network is questionable. Moreover, the integration of new terms in existing networks is difficult. If new terms arise due to new technologies or new business areas, possible connections of every existing term with the new term have to be checked. It has to be kept in mind, that the system of concepts is not a static database, which is created one time and can be used forever, but that it is a dynamic data warehouse, which has to be constantly updated and optimized by man or software. A possible help could be the use of automated crawlers, which scan documents for terms and define connections between them based on the frequency words are used in the same sentences or the same context. Another possible solution could be the definition of certain customers groups based on mental models. It is likely that similar mental models and system of concepts are connected to similar fields of experience and practice. Should it be possible to classify humans regarding to their mental models, a pre-categorized system of concepts could be applied to every individual. Research in this field could lead to a method for customized communication assistance based on the Thesauri Cube concept. Thereby customized Thesauri Cubes could be used for an optimized communication of people of one mental model group talking to people from another mental model group.

The lack of objectivity of manually created systems of concepts could also be seen as advantage. Every company uses special terms and has basic common models. Every use of the Term Cube concept increases the establishment of the company language among the employees. Although this internal establishment is very positive, the communication with people outside the company will get harder by a higher establishment of a company language. The use of the Thesauri Cube as described in chapter 3 becomes essential at this point.

The method is no method to be used in the day-to-day business. By using the method, the focus of the project is shifted away from the original engineering problem to a communication problem. Therefore, the method should only be used in an active way, if communication problems occur. This will most likely happen in fields of new business or new products. Using the method of Term Cubes in these scenarios will save time and resources by creating a common understanding of the groundwork and standardizing the language in the new fields. More over the method of Term Cubes could be used, if new people enter existing work groups or an existing company. In this scenario, the punctual, individual use of the Term Cube method is adequate. A passive usage of the method can be carried out in day-to-day business by integrating the method with other methods as described in chapter 4. Not only can the Term Cube concept be used as a stand-alone tool or for an optimized requirement acquisition, but also it can be connected to all kinds of methods and processes throughout all fields of operation of a company. This would lead to a holistic basis for methods and processes throughout the company.

Another challenge is the creation of an intuitive user interface for the application of the method. The idea of Term Cubes works due to the complexity only on an automated computer basis. However, the front end has to be an intuitive and quick to use interface. Most important, the approach can only be an optional tool giving the opportunity to help optimizing the process of requirement acquisition and other methods and processes. Like in all situations where help is offered the person concerned has to realize that he/she needs help and has to accept the offer of help.

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