Title:
New Approach of the Product-specific Knowledge Balance Based on Data Mining of Virtual Prototypes

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Introduction:
The development departments of modern companies face big challenges caused by the immensely growing product complexity with its according multidisciplinary Big Data. Not only the big worldwide operating enterprises established innovative technologies of Virtual Prototypes, even small and medium owner-managed companies already meet the challenges of this task and the corresponding Big Data. Several combinations of proprietary engineering and simulation data describe the Virtual Prototypes depending on the industrial sector, the products to be manufactured and the size of the company. The according software tools were historically implemented based on the company's development and represent in most cases isolated solutions. Besides the explicit knowledge representations, for example wiki software solutions or file-based documentations, the company-specific technology and application know-how is concealed in this Big Data. The technological evaluation of the existing Virtual Prototypes by a comparing survey is impossible.

Even if a product data management system had been implemented, it is just possible to use classifications and search for meta data according to the depth of software implementation. This can provide indications for quantities and spread of explicit technology knowledge within the various product and development domains. But the underlying proprietary data layer could expose more information regarding the current application level and the technological state of the company, respectively its products. The conceptually new developed product-specific Knowledge Balance is capable of representing this information in a transparent way.

The common concept of the Knowledge Balance is characterized by different variations of a scorecard method to evaluate the Intellectual Capital of organizations, i.e. the overall concept is universally applicable for all kind of enterprises, research institutes and universities. The three core fields Human Capital, Structural Capital and Relational Capital are the essential components of all Knowledge Balance variants. Each core field is built up by different key figures, which represent the Intellectual Capital of the organization from a bird's-eye perspective.

This approach of the product-specific Knowledge Balance is an extension of the common Knowledge Balance by another fourth element called "Technological Capital" and creates therefore a new version of the Knowledge Balance 3.0. The key figures of this element are based on several analysis results of the existing Virtual Prototypes, automatically determined by different Data Mining methodologies. With the aid of these indicators at feature level, it is possible to conclude quality findings and thereby the knowledge about the application state and included product-specific knowledge stored in the models.

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Main Sections:

Common Knowledge Balance

The common term of Knowledge Balance refers to a management tool for identification and control of intangible assets within an organization. The functional procedure and the visualization can be compared with other scorecard methods, i.e. multistage key figure systems like the Balanced Scorecard pursuant Kaplan/Norton [1]. The method takes usually place in an annual tonus with a new determination of all indicators, presented in combination with the financial balance. The results are led back to the Mission and Vision of the company and influence therefore its targets. The several variations of existing Knowledge Balance approaches are set up by peculiarities according to the type of organization or the corresponding industrial sector. An comprehensive overview is given in [2]. Newer key aspect of the Knowledge Balance development had taken place in 2004 and 2008. Several approaches consider the annual iterations and lead back indicators from the previous Knowledge Balance. At this junction, the targets were both, gathering information about and transparent communication of interim success and transmission effects. Besides this development, there was a deeper focusing on monetarily expressible key figures of intangible assets, see the "Knowledge Balance 2.0" [6]. In common Knowledge Balances contain a manageable amount of 20 to 50 items in the three core elements Human Capital, Structural Capital and Relational Capital. All indicators are scaled and weighted. Due to the applicability for every kind of organization, it is not possible to focus the indicators on individual technological details. Even with a reduction to manufacturing companies, the bird’s-eye perspective of the common Knowledge Balance prevents precise technological conclusions.

Concept of the Product-specific Knowledge Balance

The concept of the product-specific Knowledge Balance expands the common Knowledge Balance to Version 3.0 including a complete, new sector called Technological Capital. This concept clearly distinguishes between key figures of the Structural Capital and explicit knowledge. The new element of Technological Capital contains indicators according to the documentation, transfer and securing of knowledge. These indicators represent the knowledge about the company’s products and the application level of the according CAx-tools. The top-level structure of the Knowledge Balance 3.0 is shown in Figure 1.

The new sector Technological Capital contains a multistage key figure system. The analysis algorithm including the different CAx software agents provide the indicators on a lower level 0. All key figures contain an evaluation factor, weighting, classification and scaling. For the purpose of a flexible concept and the possibility of scaling to the particular use case, the concept of the key figure system contains also multiple indicator levels. These levels are numbered from fine to coarse. The key figures are aggregated to the next higher level by calculating and grouping procedures. The basic indicators at level 0 are directly calculated by the analysis algorithm. The corresponding calculation procedures can be compared with the knowledge stairway pursuant to North [3]. The knowledge stairway maps an arrangement of sub elements to the next higher level, starting with characters to the point of knowledge. Characters compose data, information is built up by data, and knowledge is a collection of links towards information. Deducing to the evaluation of proprietary design and simulation data, features and basic indicators built up quality information, which can be merged to explicit knowledge statements of the document.

The technological key figures at level 0 exhibit quantitative and qualitative characteristics. Quantitative indicators are directly calculated by the analysis algorithm and focus on common attributes like the spread of design and simulation templates, links to catalogues or feature replication mechanisms. The configuration language XML is used to perform profounder investigations by setting up proprietary detection patterns. These patterns can be configured and maintained in the company’s environment by a qualified administrator. The development and configuration of these technological key figures and proprietary detection patterns are central points of this concept. The analysis algorithm compares the existing patterns with the located data from the software agents and calculates the technological key figures. Examples of investigating the design data is given by Roj in [4], [5] with the analysis of CATIA V5 structure trees.

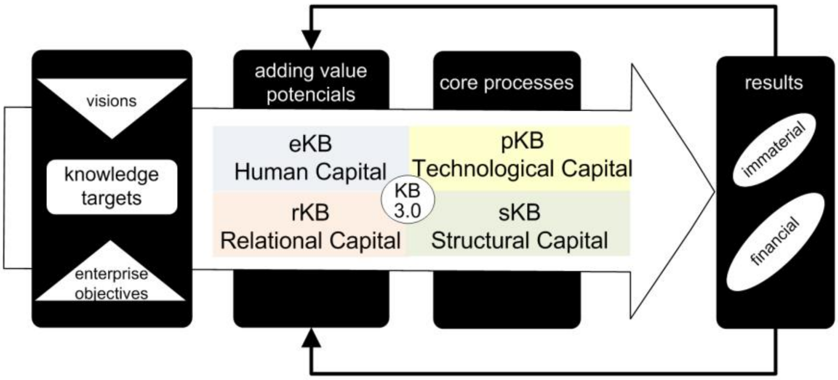

Fig. 1: product-specific Knowledge Balance as 4th element of the advanced Knowledge Balance 3.0.

Abbreviation	*Long*	*Meaning*
KB	Knowledge Balance	general term, top level view
eKB	employee-specific part	indicator sets describing the human capital
pKB	product-specific part	indicator sets with technological parameters
rKB	relational indicator sets	evaluation of relations to employees, suppliers and customers
sKB	structural indicator sets	evaluation of hardware values

Tab. 1: Overview of abbreviations.

The benefit of the product-specific Knowledge Balance concept and its obtaining knowledge is shown by two scenarios using the same data pool. Scenario 1 provides information about the current state of product data and the related application state for the purpose of decision making. This knowledge request is scalable to the corresponding issue and can be performed anytime during the development process. According to the common understanding of the Knowledge Balance, Scenario 2 calculates the Technological Capital of the company, i.e. the indicators at top level. This Technological Capital statement is transferred to the extended Knowledge Balance 3.0 in an annual tonus, according to the financial statement. But it is the application during the development process (Scenario 1) that illustrates a maximization of the benefit by more precise indicators, including a more detailed access to the proprietary data. However, in this context it is obvious, that the required expenditures are extensive. If the company uses a large number of CAx software solutions, a corresponding amount of proprietary detection patterns and software connectors must be defined. The complexity of the particular use case grows exponentially. In this context a good compromise must be achieved between the optimal coverage of all manufacturing, owner-managed enterprises as free as possible (considering the common usability) and the definition of technological key figures according to the company's products.

Technological Implementation

The described concept induces the implementation represented by figure 2. This implementation complies with different challenges, which came up using the first partial prototypes at laboratory level. The implementation mostly faces two challenging core criteria: the mandatory necessary proprietary connectors and the performance. In the presented approach and use cases, different software agents are mandatorily necessary caused by the proprietary type of design and simulation data. This extremely increases the effort of the evaluation. Considering the actual performance capacities and the described company environment, the second core criterion is based on the first one. The application of the software connectors requires larger time expenditures, so that only an asynchronous analysis of the data is suitable and therefore a temporary storage is needed for the obtained knowledge. This temporary storage for technological key figures and its results is represented by a SQL database. The aggregation of indicators at each level of the key figure system occurs in a separated calculation application. This separation is required, because the cycle time of the analysis part takes several days (according to the amount of CAx Data) in contrast to a few minutes of calculating time. Furthermore, the calculation application should be performed in a centralized way due to homogeneous and confidential results, so that an integration of this part into the user interface would also be no option. Therefore, the user access to the relational SQL database is realized by a third independent application, which can be started by the end user dynamically at any point of time. This database search at high performance provides information to the actual technological state and the product-specific knowledge amount.

Empircal Use Case and Interim Result

Considering the multiplicity of CAx solutions and the corresponding effort to configure key figures and proprietary detection patterns, the implementation at the actual laboratory stage is aligned with the subsequent empirical study and its according particular circumstances. The primarily used software solutions are the designing tool CATIA V5 and the FEM simulation tool Abaqus, both distributed by Dassault Systèmes. Even basic technological key figures can indicate the application competence and the corresponding knowledge content within one part. Also, the spread of used specific CATIA V5 modules as well as the complexity of used module functions supplies the statement about the application competence. In specific relation to the design, individual features produce hints to the intangible assets. Examples are surface models, powercopies, used formulas and relations, construction tables, links to external part geometry, structures with Boolean operations, NC processes, knowledgeware logics or sheet metal parts. Solely the corresponding numbers of usage indicate an explicit statement. This is supplied by other indicators regarding the properties of the identified elements. In addition, properly configured proprietary detection patterns allow the linkage toward the company's products. Templates for example can be recognized until a certain magnitude of change. Partially some explicit administrative identifiers exist, which can't be changed by the software end user and therefore can clearly identify the template. Further examples are component catalogues with 3D- and 2D- templates, respectively material features in the company-specific material catalogues.

Abbreviation	*Long*	*Meaning*
KBE	Knowledge Based Engineering	Knowledge based technologies to support primarily CAD
XS	Expert Systems	For a specific purpose developed knowledge methods and applications
ECAD	Electronic CAD	Computer-aided design of electronic systems
AR	Augmented Reality	Data and applications as a mixture of virtual objects in real environments
VR	Virtual Reality	Virtual environments
CACE	Computer-Aided Control Engineering	Applications for designing control systems
KM	Knowledge Management	All kinds of knowledge representation methods

Tab. 2: Abbreviations of Figure 2.

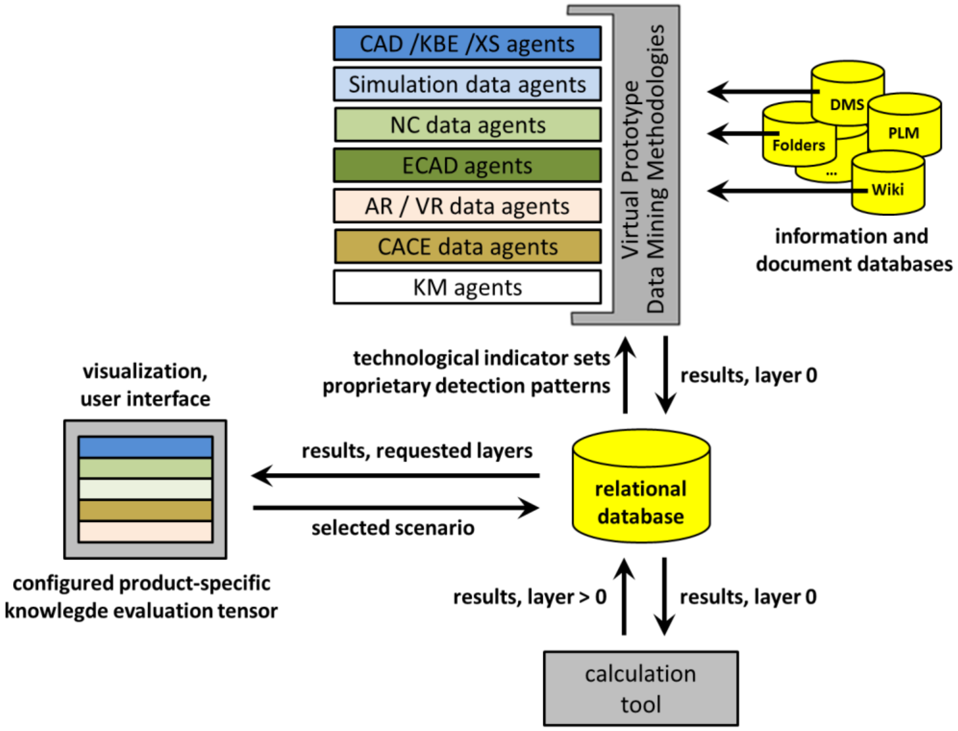

Fig. 2: Technological implementation of the product-specific Knowledge Balance.

Conclusions:
First results at laboratory stage and the configuration of the subsequent empirical study at an industrial application level show the feasibility of the product-specific Knowledge Balance concept, as well as the corresponding effort. The desired insights can be deduced from the different kinds of proprietary Virtual Prototypes with their according indicator sets. The key figure system must be aligned to the industrial empiric study and its levels must be tuned to get a well-balanced output. The significance of the calculated indicator sets, and therefore of the whole product-specific Knowledge Balance is already assessable.

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[6] http://www.wissensbilanz.de/news/, Knowledge Balance 2.0.