Semantic Enterprise

Unleashing Solution Knowledge in the Area of Mechanical Engineering

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Abstract — PROCESSUS as a particular project of the German national funded high-tech-initiative THESEUS has the objective to create an IT-based corporate system that will allow companies to compare products, solutions and details of business associates, as well as locating the complex and sometimes obscure specialist information needed by employees whose work involves high-density knowledge bases. The research teams are also aiming to develop a basic semantic platform that will integrate a company's internal planning of resources with management of the digital content of agile business processes. One specific scenario taken from the domain of mechanical engineering will demonstrate the requirements of an ontology based intra- and intererenterprise communication for solution and application retrieval in the Engineering domain. A prototypical demonstrator will illustrate the solution approach.

Keywords: PROCESSUS, ontology development, solution retrieval, product development, SOA, web service, semantic web

I. The Semantic Enterprise

These days one often comes across the vision of the World Wide Web: The Internet of the next generation, also called Web 3.0, will provide easy access to the structured global knowledge and to novel services, and crucially improve the quality of information of the relevant contents that are needed at a given moment. Also, the supply of heterogeneous services shall simplify the mapping of business processes across distributed structures. Those services might be used and marketed worldwide by their composition in complex but tailored applications. In this new semantic infrastructure, companies will also be able to communicate more efficiently with other companies and, more to the point, with their customers as well as consumers in the future. One specific scenario taken from the domain of mechanical engineering will be demonstrated in this paper. Products and solutions for the automation technology often must be adapted to the specific customer applications and use cases. A quick access to the relevant and update information – for instance from similar applications – is the key factor for an affective and efficient product development.

Within the use case PROCESSUS[1] an ontology based solution approach will be developed and evaluated that shall enable the quick and precise access to the required solution and application know-how - so that the development processes are fundamentally sped up and optimized.

A first ontology has been designed for the concrete use case of a developer of beverage packaging techniques with the goal to support the solution search by linking fundamental functions of existing products.

To this a prototypical demonstrator program has been specified and implemented that represents the process of design, product planning, solution retrieval and tender preparation for a beverage packaging plant (see Chapter VI).

II. PROCESSUS Vision

Nowadays organisations have to deal with a big amount of structured and unstructured data that are stored in different CMS, ERP, DB systems[2]. In our daily business we do need dedicated information for our different and special business processes. This information is held "somewhere" in our content assets in the organisation. But because of missing interpretation of the meaning of that information we are not able to find the right information we really need. That means we have a "semantic gap" in the interpretation of information. According to the current state of the art, "Ontology" seems to be the right medium to solve this semantic gap (OWL, RDF etc.). They are one of the basic instruments for implementing the so called Semantic Web, as they enable machines to understand what they present to the user (see Fig. 1).

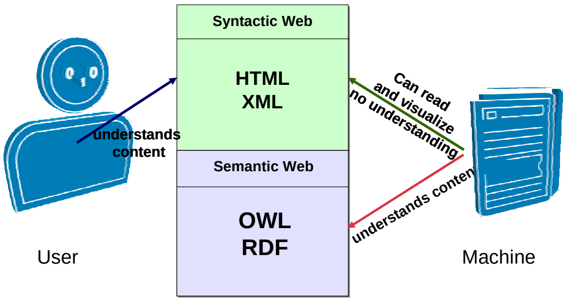

Figure 1. Syntactic versus Semantic Web

The basic idea of the semantic business process integration platform PROCESSUS is to give users selective access to the unstructured data found in emails, minutes of meetings, offers, etc. First of all there is a need to bridge the specialities of terminology and domain knowledge within data pools and processes. We achieve that by using knowledge models (ontologies) via term abstraction and a

[1] PROCESSUS is one use case within the THESEUS-Program, partly funded by the German Federal Ministry of Economics and Technology (http://theseus-programm.de).

[2] Merrill Lynch estimates that more than 85 percent of all business information exists as unstructured data - commonly appearing in e-mails, memos, notes from call centres and support operations, news, user groups, chats, reports, letters, surveys, white papers, marketing material, research, presentations and Web pages.

context based view. On the one hand this approach assures the access to already existing company knowledge and the reuse of approved solutions, on the other hand the execution of specific business processes might be automated by "semantization" of single process steps.

A prototype Business Integration Platform will be designed for this purpose, incorporating tools for the semantic accessing of content and contextual relationships in collections of unstructured data. The emphasis will be on new components and services, or the expansion of existing ones. A few examples are:

- Content Management (creation and editing of content that requires semantic enrichment)
- Content Usage (semantic search, reasoning, semantic classification, reuse of content)
- Ontology Administration (creation, import, export, maintenance, etc.)
- Domain specific Ontologies for selected application domains (drive and automation technology)

The Vision of PROCESSUS is a "Butler" who gives us the right and needed information - independent of its storage place and format - in the process context and process step that a user works on in the moment of his search request. This requires innovative retrieval technologies and is based on the usage of ontologies and semantic annotation of the information fragments. PROCESSUS shall also support the design and execution of the designated business processes by semantic and context controlled process steps (see Fig. 2).

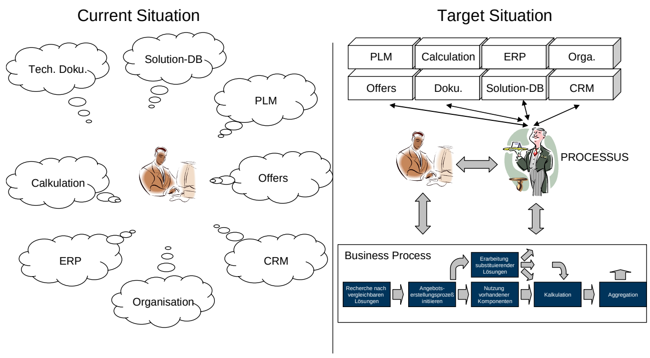

Figure 2. The PROCESSUS Vision

The horizontal PROCESSUS platform enables vertical applications for different usage scenarios on top of it. Solution features for different domains and industries will be made available as web-services, orchestrated on a SOA-platform environment. While a SOA platform creates the environment to run the web-services [1], the collection of the basic services (such as content management, ontology management, content classification, workflow management, access management etc.) will build the PROCESSUS platform technology.

Typical user groups are sales and production staff that require continuous, unrestricted access to the company's store of knowledge about the functions and possible applications of products and solutions. At present, software systems provide only inadequate support for this kind of search for knowledge about products or solutions.

These days, the heterogeneous nature of the information in question, and the almost infinite range of different viewpoints of those providing or consuming information (e.g. Marketing, Sales, System Engineers, Designers, Customers, etc.), represent a very real challenge; no set of standards yet exists that would allow these heterogeneous viewpoints and their respective specialised terminology to be linked systematically and consistently. The use of ontologies will guarantee a standardised knowledge transfer.

III. Existing Sources of Information in the Domain of Mechanical Engineering

To give a brief overview of the present situation in the area of mechanical engineering, some existing sources to support a developer with the needed information about solutions are presented. Also some deficits of these sources are shown.

Many different approaches exist to support the developer with the needed information. For the search for active principles, collections of physical effects exist (amongst others [2], [3] und [4]). Also databases with effects from various areas of natural science can be used (amongst others CREAX[3], GINA[4] and GoldfireInnovator [5] - formerly Techoptimizer from Invention Machine). Furthermore a variety of product catalogues, construction catalogues and internet based databases delivers requested information. The internet gains increasingly an important role in delivering this information. Several market platforms (e.g. VDMA-e-Market[6] und Xpertgate[7]) exist which offers the opportunity to search for products of more than one company.

These existing sources have some deficits. Either they are very abstract (collections of physical effects) or quite a huge amount of knowledge is needed using them (construction catalogues). If the user doesn't know the necessary terminology for the source, it costs a lot of time to find the needed information. Furthermore the search for and the comparison of products from different companies is very time-consuming. The maintenance of market platforms is very challenging as the heterogeneous viewpoints and terminologies of the included companies have to be provided. All the presented approaches have the deficit of a real function-oriented search which connects functions to the complete product.

IV. Benefit of Ontologies and Semantics for the Search Process

A. *Ontologies in PROCESSUS*

In comparison to the present approaches which basically describe products and solutions by data, variables and product descriptions, PROCESSUS focuses on an application-oriented representation of the information. This representation is based on functions. Functions are – one step after the product requirements – the most abstract description of a system [3]. They can be used to bridge the gap between task and solution. A function is described by an object and an operation ([5] and [6]). Both object and operation can be described by several properties. These properties are stored in the PROCESSUS ontology by classes, properties and individuals.

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[3] CREAX - creativity for innovation, URL: http://www.creax.com/
[4] GINA-Innvoation-Tools, URL: http://user.gina-net.de/main/
[5] Invention Machine, URL: http://www.invention-machine.com/
[6] VDMA-e-market, URL: http://www.vdma-e-market.com
[7] Xpertgate – Portal für Fabrikautomation, URL: www.xpertgate.de

The ontology supports the user (e.g. the developer within a beverage packaging systems manufacturer) in finding solutions and products for different subsystems or subtasks of the system he wants to develop. The search is not limited to known and applied solutions within the own company but also contains the research for possibly fitting products from other areas of interest, which can be found in the intra- or internet.

Thus the description of components and products is extended with the knowledge of the related application. As there are many different heterogeneous viewpoints in the various areas of mechanical engineering their respective specialized terminology has to be linked systematically and consistently. To achieve this, further classifications and taxonomies are integrated in the ontology.

B. *Description of the present approach in the use-case*

Based on an example the present approach will be described. A product development engineer from a company offering system solutions for the layout of plants is looking for solutions to a sub-system of a new packaging station. One important subsystem of the packaging station is the transfer of bottles. Since the solution has to be cost efficient, but of high quality, the engineer wants to investigate alternative principle solutions first before looking into specific components from particular manufacturers. The consideration of competing technologies for a given application is currently rarely supported in existing systems. At present, providers as well as clients of knowledge are faced with a huge complexity due to extremely heterogeneous contents and inadequate access mechanisms. Here, the PROCESSUS platform provides a semantic connection between requirements, functions, solution principles and corresponding products.

By searching with the keywords “transferring a bottle” (representing function and application), the designer is supported to describe his problem in an abstract and more general view, e. g. “moving a cylindrical workpart”. The relationships between the concrete problem descriptions and the general concepts are implemented in the domain specific ontology for the packaging industry. After describing his problem the engineer is led to a number of promising solution principles (e.g. mechanical, hydraulic, and pneumatic). The solution itself is linked into the ontology in the same way the designer described his problem. Whereas the product is described with “packaging of beverages” the ontology supports abstracting the function of the product and describing it in a more general way with “moving a cylindrical workpart” (see Fig. 3).

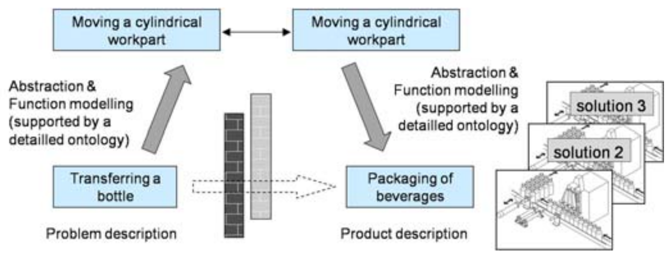

Figure 3. Linking problem and produkt description – conquering the semantic barrier

By setting further requirements (“batch quantity, merchandise, packaging material, etc.”), the solution space can be narrowed down and different solutions and products as well as a number of companies offering these products are returned as result

V. Development of the Ontology

The ontology is developed in the context of the use-case described above. Based on several product descriptions in the area of packaging technology, the ontology is built step by step and increased continuously. In further steps the ontology can be enhanced by integrating products of other areas of machine or plant engineering. The ontology can be divided into two parts: the first part stems from the description of the functions of the system. It creates the base structure of the ontology. The second part results from the approach of describing different viewpoints of the solutions. Within a further classification and taxonomy it is possible to embed different views of different industrial sectors.

A. *Procedure of developing the ontology*

The different steps to build the ontology are shown in Fig. 4. Based on existing product descriptions (in this case: packing machines), functions are extracted by annotating text. Redundant terms of semantically equal meaning (e.g. bottle, flask, PET-bottle, etc.) are then eliminated. The outcome is a function list in which the functions are linked to the related systems (function owners), objects and operations. The links between the function owners and functions form the basis for the ontology. The structure of the classes and relations results from the requirement that the functional modelling of the product can be described completely.

In the next step this ontology is filled recursively with information about other solutions from the packaging technology and is complemented with additional classes and relations when required.

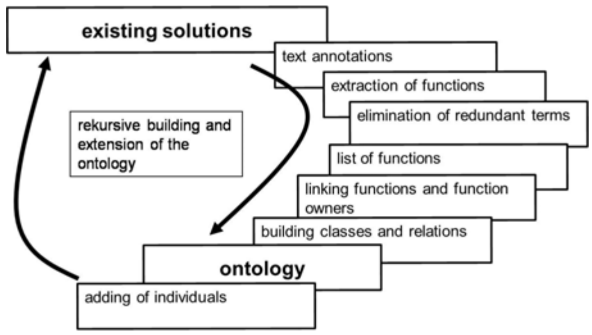

Figure 4. Development of the ontology

The demonstrated steps are performed manually so far. Yet, the aim is to scan existing solutions automatically for relevant functions and objects and embed them in the existing ontology.

B. *Base structure of the ontology*

The base structure includes the classes and relations of the highest hierarchical level. Here the functions of a product, the relevant industrial sector in which the products are used, properties and operations are described. The base structure of the ontology can be illustrated simplified as shown in Fig. 5. The function has the central position. It is used in a special industrial sector, executed by a function owner and performs a certain operation on a decent object. In addition, objects can have defined properties.

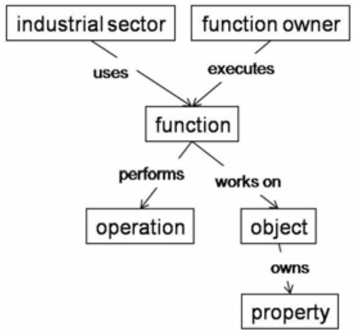

Figure 5. classes and relations

Within the several classes of this base structure, further classification contains subclasses which assure detailed distinctions of all contained data. The individuals (function individuals, object individuals, etc.) are filtered out of the text annotations and related with the appropriate subclass.

C. Organising pinziples for integrating different viewpoints

Besides the representation of the semantic connections in the base structure, different views on the deposited terms and concepts are modelled. They are integrated into the ontology in further organising principles.

Using the example of the functions, the concept of the organising principles will be described. In Fig. 6 the existing connections are shown. Taking different views on an existing solution out of different perspectives, several functions exist to describe one possible solution. For example, different companies describe - according to the particular industrial sector (assembly technique, packaging technique, etc.) - their solutions and products in a different way:

- Company A, a manufacturer of robots for different assembly tasks, describes its solution for the packaging of bottles into boxes with the function "handle bottles".
- Company B, a manufacturer of pneumatic components and related system solutions describes its solution as transfer system for bottles with the function "transfer or transport flasks".

Both views are considered in the ontology in the form of organising principles. Hence, functions which describe similar or equal tasks or jobs can be integrated in separate taxonomies – according to their industrial sector.

However, both classes possess properties and specifications of significant attributes which enable building a relationship between them: Both of the functions can – on a more abstract level – change the position of an object. With this commonality it is possible to automatically sort them by reasoning of the ontology and combine them in the more general class "change position".

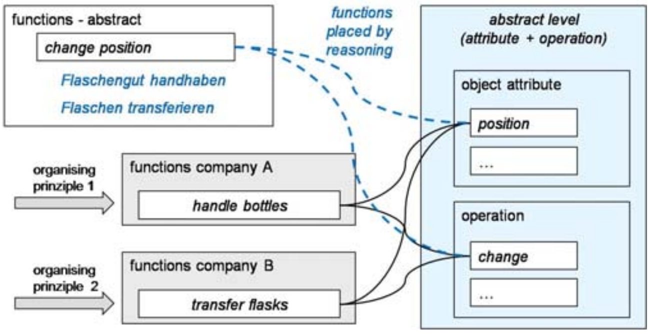

Figure 6. Reasoning of different views to an abstract class

Thus, different views can be collected independently in different organising principles and connected afterwards by reasoning.

VI. Ontologies in use

A first demonstrator program has been specified and implemented which shows the process in operation according to the defined scenario. The final objective of this program is to show the information on its way along the value chain from the point of its creation to its usage, and its annotation for different publications and organisational units by involving also third party services (SOA). The essential semantic technologies in use are metadata, ontologies, web services and Business Process Management (BPM).

By now, the demonstrator represents a specific scenario and is able to support a Sales Person in writing a tender: Mr. Markus Sell, a sales executive from the plant manufacturer Semantic Machines, has the task to submit a bid for a beverage plant to the customer Sprockhövel GmbH.

After his login on the PROCESSUS platform, Mr. Sell enters his work space. He tells PROCESSUS what he is going to do and will be henceforth interactively assisted by the system until his bid will be finished and archived for further reuse. Some steps shall be illustrated during the conference presentation; here a few screenshots are shown:

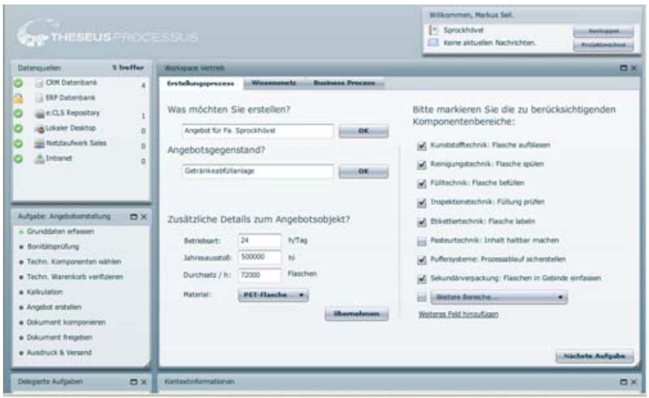

Figure 7. Interactive preparation of a tender

The tender process starts with the input of basic data by the sales person while the system constantly refreshes the result lists for a suitable solution to be reused, according to the context information and the user's workflow (see Fig. 7).

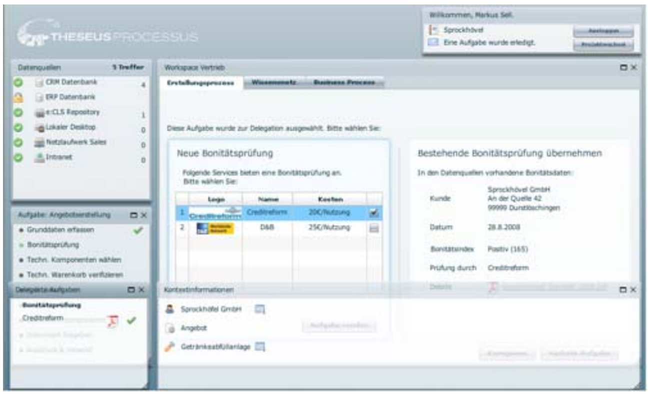

Figure 8. Embedding of third party services

Fig. 8 shows the benefit of the SOA based system. According to the defined business process, the step of credit assessment has to be performed before the concrete planning of the plant starts. This assessment is provided by a selection of specific web services. Here, Mr. Sell opts for one of those services by ticking the box. While Mr. Sell goes on, the assessment task runs in the background. After a while the system comes back with the relevant statement.

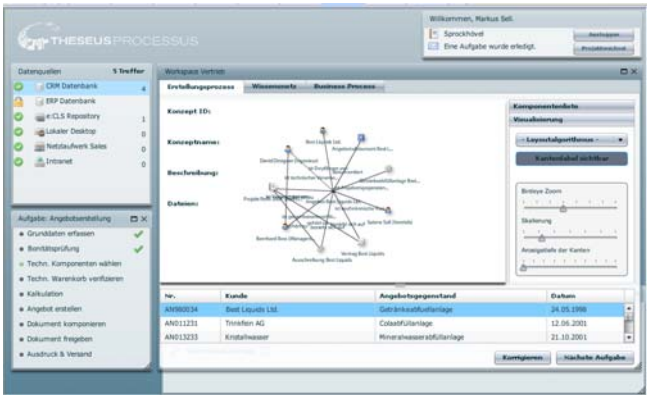

Figure 9. Different views of the proposed solution

By selecting one of the retrieved tender documents in the list the relevant tender will be visualized with all its context information in the upper part (see Fig. 9). Now Mr. Sell can navigate through the graph and gather all relevant parts for his new tender by just dragging and dropping them to his component list. Subsequently some more steps will be performed until the new tender will be finished, approved and sent to the customer. The system automatically stores the new data in a structured way and thus makes them available for the next reuse by any authorized employee.

VII. Conclusion

The deployment of the depicted approach of content usage and solution search in the automatization domain might offer big competitive advantages. But before this, the knowledge base has to fulfil different requirements, especially the alignment of existing classifications. The real challenge is the mapping of terminology and structure of products and solutions from all kind of manufacturers.

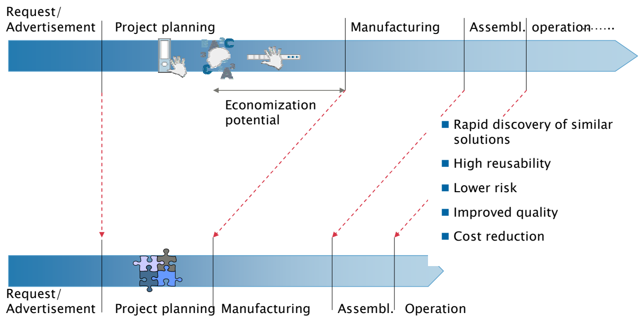

Figure 10. Competitive Advantage

In total, an improvement of the complete process is feasible, because the relevant information is quickly accessible, decisions are well prepared, the interactive process runs more smoothly, and the internal/external document exchange is done more efficiently. Especially, the planning and design phase can be arranged more profitable up to 50% in time and budget, due to better search and finding of existing similar solutions (see Fig. 10).

This scenario has been illustrated with examples from the drive and automation industry but is also generally applicable for knowledge transfer in other business sectors which deal in knowledge creation and management. For knowledge providers, especially SMEs participating in the e-marketing-platform, the PROCESSUS approach provides adequate mechanisms to display their competencies and available solutions on the market and attract possible clients in a more efficient way than before.

This solution evolved from the cooperation of the Verband Deutscher Maschinen- und Anlagenbauer (VDMA), the Technical University of Munich, and partners from the industry, among them Festo AG & Co. KG, SAP AG and empolis GmbH.

Literature

[1] N. Bieberstein, S. Bose, M. Fiammante, K. Jones, and R. Shah, "Service-Oriented Architecture Compass," IBM Press, 2005.

[2] K. Koller, N. Kastrup, „Prinziplösungen zur Konstruktion technischer Produkte," Berlin: Springer, 1994.

[3] J. Ponn, U. Lindemann, „Konzeptentwicklung und Gestaltung technischer Produkte," Berlin: Springer, 2008.

[4] K. Roth, „Konstruieren mit Konstruktionskatalogen. Band 2: Konstruktionskataloge," Berlin: Springer, 1994.

[5] K. Ehrlenspiel, „Integrierte Produktentwicklung – Denkabläufe Methodeneinsatz Zusammenarbeit," München: Hanser 2007.

[6] G. Pahl, W. Beitz, J. Feldhusen, K. H. Grote, „Konstruktionslehre," Berlin: Springer 2005.