Product Knowledge Management Support for Customer-Oriented System Configuration

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Abstract. Due to the changes in global markets, companies strive for attracting and retaining customers in various ways. The paper investigates the problem of product configuration knowledge management in a customer-oriented way and how it has been solved. The authors' vision of required improvements in business processes and knowledge-based systems at the considered company is shared. Nevertheless, the presented work can give significant input to achieve benefits for component manufacturers that tend to become system vendors in general.

Keywords: Knowledge management · Customer view · Application view · Automation

1 Introduction

Due to the changes in global markets, companies strive for attracting and retaining customers in various ways [1, 2]. The situation is the same in every market where there is a long history in the regarding type of products. Multiple product manufacturers and vendors are present and there is not much room for new products, unless they are really innovative. The markets are shrinking and companies striving for attracting and retaining customers see service provision as a new path towards profits and growth.

Achievements in the area of artificial intelligence (AI) open new possibilities for increasing customer satisfaction from customer-driven design to reduced lead-time. The current wave of progress and enthusiasm for AI began around 2010, driven by three mutually reinforcing factors: the availability of big data from sources including e-commerce, businesses, social media, science, and government; which provided raw material for dramatically improved machine learning approaches and algorithms; which in turn relied on the capabilities of more powerful computers [3]. Therefore, adaptation of information & knowledge management in companies to the new trends is mandatory to succeed in the current situation.

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Today, in the era of Internet of Things, "products generate a large amount of information during their lifecycle. … Several tools of product lifecycle management have been developed in the last years to address this issue, but they are rarely exploited by companies, especially SMEs" [4]. The presented research is aimed to address the 3Vs of big data, which are considered as major pillars of efficient information & knowledge management: volume, variety, and velocity [5]. Recently, there have appeared multiple ideas on increasing the number of Vs, however, "they only bring big data into the realm of traditional data processing and analytics" [6]. The volume and velocity in the discussed work are dealt with through incorporating software services aimed not only to complement the products (offering customers product-service systems instead of pure hardware systems) but also to accumulate usage statistics for further analysis. This makes it possible to better understand customers' needs and indirectly involve them into the product and system design processes ("customer-driven design"). The ontology-based knowledge representation facilitates solving the problem of variety.

The paper is based on the analysis and modification of the knowledge management processes related to system configuration and engineering at the automation equipment producer Festo AG & Co KG. Festo is a worldwide provider of automation technology for factory and process automation with wide assortments of products (more than 30 000–40 000 products of approximately 700 types, with various configuration possibilities) ranging from simple products to complex systems.

Around the world, 61 Festo national companies and 250 regional offices in 176 countries ensure that advice, service, delivery quality, and reliability precisely meet customer needs in all global industrial regions. Today, more than 300,000 industrial customers in 200 industry segments worldwide rely on Festo's problem-solving competency. It produces pneumatic and electronic automation equipment and products for various process industries in 11 Global Production Centres and 28 National Service Centres [7].

The paper investigates the problem of system configuration knowledge management in a customer-oriented way and the how it has been solved. Implementing such an application-system view addresses the problem of designing the customer view on system selection, configuration, and usage, i.e. defining user experience by "talking in a customer-understandable language" and addressing customer's application problems.

Obviously, considering the company's scale, processing data about products sold to each customer necessarily deals with the big data. The paper shares the vision of the authors of required improvements in business processes and knowledge-based systems at the considered company related system configurations to address the 3Vs of big data. Though the research results are based on the analysis of one company, the presented work can give significant input to achieve benefits for component manufacturers that tend to become system vendors in general.

The remaining part of the paper is structured as follows. The next section describes the research methodology applied. Then, the approach centralised around the new configuration view is proposed. It is followed by the description of the corresponding changes in company's IT systems. Section 5 presents the case study example. Section 6 outlines the major findings obtained. Some summarizing remarks are presented in the Conclusion.

2 Research Methodology

The used gap analysis methodology [8, 9] was implemented through the following steps. First, the analysis of the current organisation of the information & knowledge management in the company was carried out. Then, the expert estimation of the company benchmark was done. Based on this, the comparison of the present and future business process and knowledge management organisation was done resulting in creating corresponding process matrixes. This has made it possible to identify major gaps between the present and the future business organization, analyse these and define strategies to overcome these gaps.

Research efforts in the area of information management show that information & knowledge needs of a particular employee depend on his/her tasks and responsibilities. Even within one company representatives of different roles like product managers, sales personnel, etc. have different needs when interacting with an application like a system configurator. However, if managers or sales representatives, for example, might know about the products and are able to configure by deciding on technical facts, the customer, usually doesn't know about the technical details of the company's products or even what kind of product he/she may use to solve his/her application problem. This is the reason why technical product details should be hidden from the customer under the application layer. As a result, the customer-oriented configuration process has to be based on the system application.

3 Application View

As it was mentioned above, the customer-oriented system view comes from the application side. After defining the application area, configuration rules and constraints to the system are defined. They are followed by characteristics and system structure definition. Finally, the apps (software applications) enriching the product functionality or improving its reliability and maintenance can be defined. The same applies to the sales stage.

As a result, implementing such application-constraints-system view addresses the problem of designing the customer view on product selection, configuration and processing (defining user experience, "talking in a customer-understandable language") [10].

Based on different complexity levels, the company's products can be classified as simple discrete components, configurable products, or system configurations. The major goals are (1) reducing the effort in producing products and (2) reducing the time-to-delivery to the customer. For this purpose, three levels of complexity are differentiated:

- PTO – pick to order: A product is order-neutrally pre-fabricated and sold as a discrete product. This means that no configuration is necessary to identify the correct combination of components. The different combinations already exist and for the customer it is a selection process rather than a configuration process. No order-specific production is required.

- ATO – assemble to order: The different components a product can be composed of are pre-fabricated but the correct combination of components is left open for order clearing process. The product itself is order-specifically produced from these existing components.
- ETO – engineer to order: A product is based on a known set of pre-fabricated components (like in the ATO scenario) but the specific customer need requires additional engineering activity. In this case, new components need to be engineered, constructed, and fabricated in order to fulfil a customer order and product the order-specific product.

Both goals (reducing the effort in producing products and reducing the time-to-delivery to the customer) should be reached by having less engineering activity (ETO) but more products that can be assembled based on a pre-defined modular system (ATO). In this sense, it is intended to make use of the “economies of scale”. Products of different complexity require distinct handling in the process from request to delivery.

Of course, the selection and configuration of these different types needs to be addressed accordingly. However, the customer should not be aware of this distinction. To the customer, the sales process should always “feel” the same.

As it was mentioned, different information & knowledge needs of different roles (product managers, sales personnel, customers, etc.) are the reason to hide the technical product and service details under the application layer. In addition, the selection of the right product for solving the application problem can be based on a mapping between the application layer and a (hidden) technical product layer. In the optimal case, a customer does not notice whether he/she is selecting a discrete product, configuring a complex system, and so on.

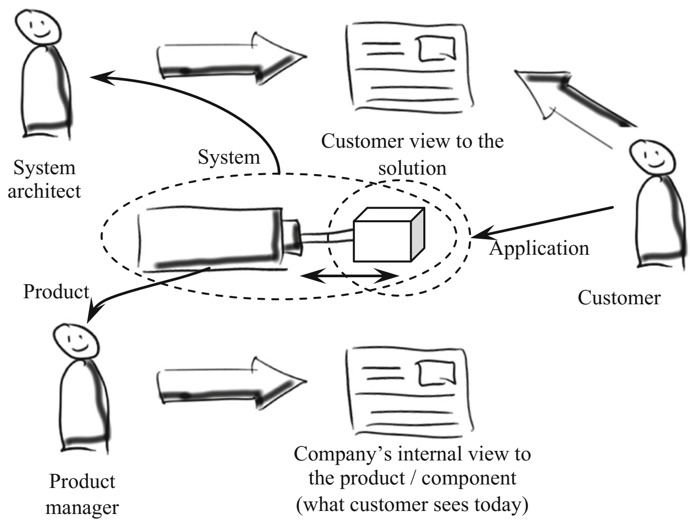

Fig. 1. The shift from the product view to the system view.

As a result, the overall concept of customer-centric view on the products has been formulated as shown in Fig. 1. It includes the introduced above new role of "System architect" responsible for the holistic view to the system and its configuration, description of its functionality and applications, and designing a customer view to it.

4 Changes in IT Systems

The changing requirements on business processes also induce changing requirements on IT systems.

In today's world, most companies do system specification with MS Word documents or similar approaches. These documents are handed over to construction. Construction hands over other data, e.g. technical characteristics via PDM systems or CAD files, to manufacturing, and so on. At the time a sales channel is set up for the new system, the initial data from product specification is lost. In the world of big data, this approach cannot survive. Thus, a new requirement for effectively setting up sales configurators and after-sales support is a continuous database. Knowledge about the system's application domain should be formally acquired already in the early phases of new system development.

A modelling environment must be capable of designing modular system and product architecture. This means that using such an environment, it must be possible to reuse single product models in the scope of system configurations and assign product or system models to application knowledge. This requires the definition of well-formed product model interfaces to allow for modularity. Such interfaces enable a black-box approach, in which all products or modules implementing this interface can be chosen for the complex product/system; i.e. they become interchangeable. For the customer the complex details of product models on lower levels of the system architecture remain invisible. The customer decides based on the visible characteristics of the black-box.

Finally yet importantly, it is also important to support multi-user activities on the different parts of product, system and application models without losing track of changes and implication that such changes have.

5 Pilot Case Study Implementing the Developed Approach

The developed approach has been verified on a pilot case for the Control cabinet system. This is a complex system consisting of a large number of different control elements, some of which are also complex systems. Due to variety of components, its functionality is significantly defined by the software control system. Control cabinets are usually configured individually based on the customer requirements since their configurations are tightly related to the equipment used by the customer.

Before the change, the customer had to compile a large bill of materials by deciding individually for every single component, in order to get the control cabinet. Now, with a holistic view to the control cabinet as to a single complex system including corresponding apps and software services, it can be configured and ordered as one product.

At the first stage, based on the demand history, the main requirements and components are defined at the market evaluation stage.

Then, at the engineering stage the components, baseline configurations based on branch specific applications as well as possible constraints are defined. This was done on the top of earlier developed ontology (see [11] for details). The ontology was built around the 4-level taxonomy based on the VDMA classification (Verband Deutscher Maschinen- und Anlagenbau, German Engineering Federation, [12]). Taxonomical relationships support inheritance that makes it possible to define more common attributes for higher level classes and inherit them for lower level subclasses. The resulting ontology consists of more than 1000 classes. The same taxonomy is currently used in the company's PDM and ERP systems. For each product family (class) a set of properties (attributes) was defined, and for each property its possible values and their codes were defined as well. The lexicon of properties is ontology-wide, and as a result the values can be reused for different families. Application of the common single ontology provides for the consistency of the product codes and makes it possible to reflect incorporated changes in the codes instantly.

Complex product description consists of two major parts: product components and rules. Complex product components can be the following: simple products, other complex products, and application data. The set of characteristics of the complex product is a union of characteristics of its components. The rules of the complex products are union of the rules of its components plus extra rules. Application data is an auxiliary component, which is used for introduction of some additional characteristics and requirements to the product (for example, operating temperatures, certification, electrical connection, etc.). They affect availability and compatibility of certain components and features via defined rules. Some example rules are shown in Fig. 2. The figure represents a valve terminal (VTUG) and compatibility of electrical accessories option C1 (individual connecting cable) with mounting accessories (compatible only with H-rail mounting) and accessories for input-output link (not compatible with 5 pin straight plug M12). These rules are stored in the knowledge base and can be later used during configuration of the valve terminal for certain requirements.

The result of this is a source information for creating a cabinet configurator tool that makes it possible for the customers to configure cabinets based on their requirements online. At this stage, such specific characteristics are taken into account as components used, characteristics and capabilities of the cabinet, as well as resulting lead time and price (Fig. 3).

Based on the customer-defined configuration the engineering data is generated in an automatic (in certain cases – semi-automatic) way, which is used for the production stage. As a result, the centralized production of cabinets is based on the automatically generated engineering file (Fig. 4).

The new business process made it possible to reduce the time from configuration to delivery from several weeks to few days (depending on the required components). The attitude of the customers is yet to be analysed since so far they have approached the new process as an experiment and not as routine work. The system maintenance has also been significantly simplified due to the system-based view. All the knowledge about this product (not only separated components) is available and can be used for modification of its configuration on customer's demand.

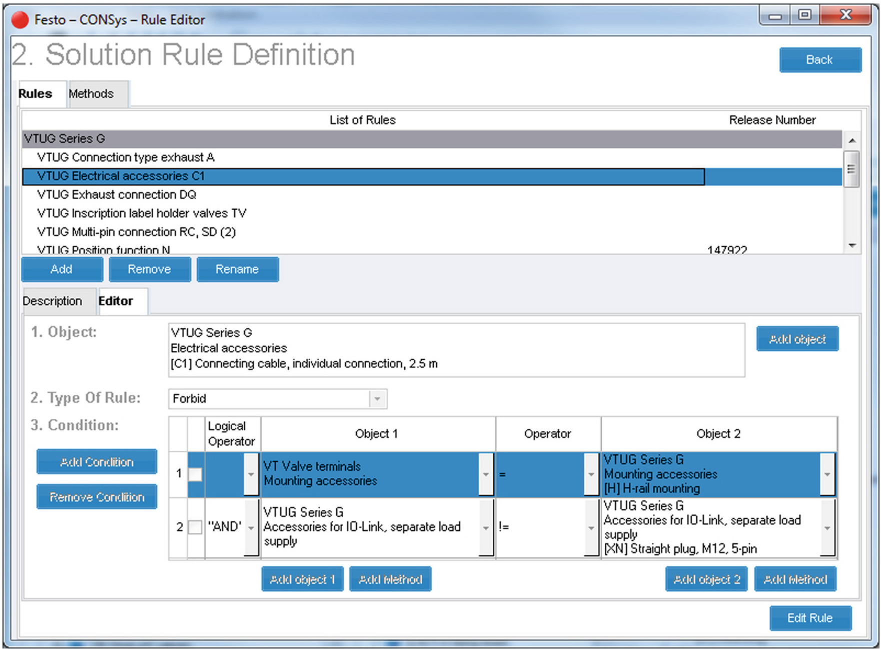

Fig. 2. Rules example.

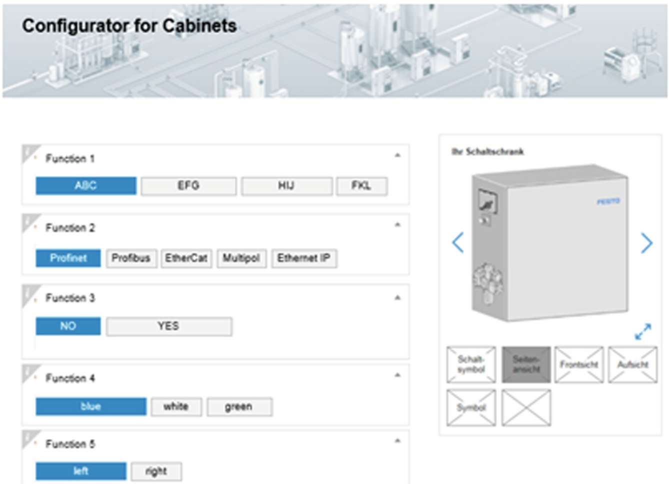

Fig. 3. Control cabinet configurator: an interface example.

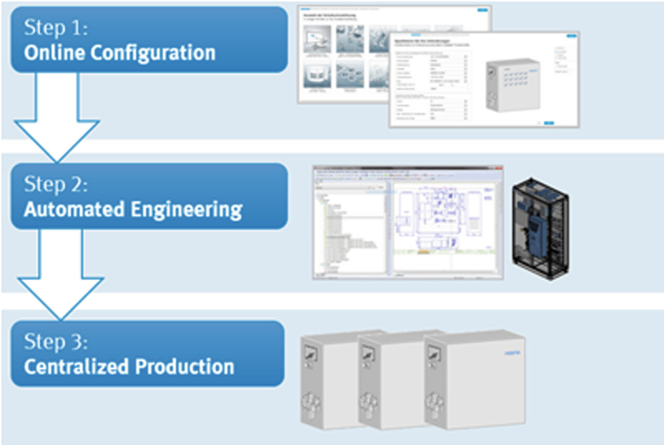

Fig. 4. Control cabinet: from online configuration to production.

6 Findings

As a summarization of the findings of the described work, the following main strategies of the servitization processes have been identified:

1. Designing customer view on product selection, configuration, and processing.

There are different types of users, like product managers, sales personnel, or customers. These users have different needs when interacting with an application like a product configurator. The customer view and the company's internal view describe two contrary views addressing the intersection between the company's product diversity and the customer's individuality with a common goal: being able to guide a customer in selecting and configuring the right system for his/her application problem. At first sight, diversity and individuality seem to have a lot in common, but the goal behind each is rather distinct. It is important to analyse the customer's context (especially for offering services): system usage, customer's industry, who does the maintenance, country-specific regulations, etc.

2. Increasing system modularity/reusability in the context of complex systems and big data.

The structure of product combinations and systems needs to modularized. Comparable modules have the key ability to be used in multiple configuration contexts. This concerns not only products and components, but also product combinations and whole systems assuming building a multilevel system engineering model. Thus, a general system model architecture needs to be set up.

3. From business processes to IT and vice versa.

Though it is reasonably considered that the changes of business processes are the driver to changes in the corresponding IT systems, the experience has shown that it is not always the case. Having defined a general strategy, the company can try to implement some pilot particular IT solutions to support existing business processes or parts of them. If such solutions turn out to be successful, they could be extended and will cause changes in the business processes.

Besides the above strategies, some more particular findings with impacts on business processes and knowledge-based systems can be identified as well.

The impacts on business processes include:

1. Aligning the business processes (improving interoperability and avoiding redundant tasks). When building a new configurator platform, it is important to align business processes like new system engineering together with the desired outcome. Doing so can help improving interoperability and avoiding redundant tasks e.g. in data maintenance.
2. Setting up sales and pricing strategies. While for tangible products, the price is typically based on the production costs plus some margin, pricing for systems is more complex and requires development of new sales strategies.

The impacts on information systems include:

1. Homogenizing and standardizing master data (increasing master data quality; e.g. for being able to compare components, which are necessary to build partially defined combinations and systems).
2. Implementing IT support for the changed processes (supporting the improved business processes).
3. Systems' needs have to be defined. This includes information and knowledge related to components/machines, software, and valid combinations of hardware and software components.
4. Statistics need to be recorded and interpreted.

7 Conclusions

The paper presents results of the ongoing shift from separate product and component to integrated systems offering. In particular, it is concentrated on improving customer experience in configuring and ordering for configurable systems. The core idea is the change from the convenient for the company view of the products to the customer-friendly view from the system application perspective, which required an introduction of a new role of "System architect". The developed business process and supporting IT systems made it possible to implement the scenario of the automated production of the customer-configured control cabinet.

The presented work is an ongoing joint research, which is still in an intermediary step of implementation. So far, a pilot case for the control cabinet product has been implemented together with the CPQ (configure – price – quote) software vendor encoway GmbH. This configuration application is already in use for selected customers. The future work will include achieving automated production of other customer-configured systems. The research is based on the study carried out in the company Festo AG&Co KG, however, the results can give significant input to achieve benefits for component manufacturers that tend to become system vendors in general.

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