Design for Customer – Sustainable Customer Integration into the Development Processes of Product-Service System Providers

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***Abstract*— The importance of integrated product-service provision has been well-recognized in both academia and industry alike. However, substantial deficiencies still can be found in the areas of integrated product-service-development and customer integration. The approach 'Design for Customer' postulated within this paper highlights a possibility for continuous customer integration during the utilization phases of a product-service system enabling a constant portfolio alignment according to customer requirements.**

***Index Terms*— Product-Service Systems, Product-Service Development, Customer Requirements Management, Configuration Management**

I. Introduction

ACTUAL changing market constraints result in an aggravated international competition as well as in the subsequent homogenization of the offered products regarding technical and qualitative aspects. In addition, customers increasingly demand integrated solutions fitting their very individual needs instead of buying standardized physical products [1]. Consequently, typically product-centered manufacturing companies encounter the need to serve each customer in a more individual way and thus to set up differentiation potentials in comparison to competitors. One way of doing so is to offer integrated value bundles – often referred to as product-service systems (PSS) – as they consist of intangible services and physical products [2]. Thus, what the customer buys is not a simple product or a simple service anymore but instead a problem solution or some kind of business functionality [3]. In consequence, product and service components are becoming intertwined and new hybrid structures for an individual solution business arise. Such a step is accompanied by a change in the vendor's self-conception from manufacturer to solution provider. The solution provider benefits from an increased differentiation potential as well as from an increased customer proximity. The customer on the other hand profits from an added value brought by an integrated product and service offering [4] [5]. Consistently, most companies surveyed in a study regarding their future strategic direction plan to expand their solution business. 98% of the companies intend to drive their business by offering integrated value bundles instead of pure products [6][1].

However the transformation from manufacturer to solution provider is associated with multiple efforts. Thus, the integrated development of products and services requires a complete renewal of product development processes in order to provide an added-value to the customer. Yet, within industrial practice, only half of all companies are synchronizing their products and services already within the development phase [6][2]. On the other hand, solution providers need to establish an intuition about the real necessities of each customer in order to serve in an individual way. Thus, the customer needs to be incorporated into the processes of the solution provider holistically. Actual studies however exemplify a utilization of classical and hands-on methods for customer incorporation and customer requirements analysis. Consequently, almost half of all companies are unsatisfied with the identification of the customers' needs and requirements [6][3].

The present paper gives assistance in the addressed topic and proposes a new approach for continuous customer-integration also beyond the development phases of products and services. The formal capturing of customer knowledge envisioned within the approach enables a constant feedback stream of customer requirements into the solution provider's development processes. Thereby the approach is supported by reference models enabling a synchronized product and service development utilizing the acquired customer feedback data.

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II. Motivation

Due to the short history of product-service systems research, this area still exhibits manifold research questions as already briefly outlined within the first chapter. The incentive for the present work is rooted within some of these open questions which will be discussed in the following chapter.

A. *Need for pre-defined integrated solution portfolios*

Within industrial reality, the planning and development of the product business as a historical core competence of manufacturers is based on methodically established foundations and follows a structured way. In contrast, deficits can be found regarding the range of services since methods and tools for a structured planning and development of integrated product-service-bundles are only provided to an inadequate extent. Therefore, the development of the bundles within industry happens in an unstructured way and ad hoc in response to specific customer requests. In doing so, the fact that the economic success of a product-service system is significantly dependent on its conception is considered only to an inadequate degree. Appropriate process models for the structured planning and development of product-service systems are the focus of research since a few years. A detailed state-of-the-art report regarding existing process models can be found in [12].It is the purpose of such process models to support the development of a PSS in a structured manner and in repeatable high quality [13]. However, their high level of abstraction prohibits an easy adoption in industrial enterprises.

Yet, a more concrete support is provided when using conceptual models for both planned and existing product-service systems. As the conceptual modeling is a time and cost consuming effort, it is reasonable to use existing reference models as a starting-point for deducing conceptual models and adapting them to the company's needs. Reference models provide best-practice processes, which can be adapted to aid companies in designing and operating their business. Accordingly, reference models are used when quickly adaptable basic concepts for implementing business processes and a speed up of the design of information systems are needed [14]. Thus, adapting reference models can lower a company's risk to adapt potentially unsuccessful and non-verified concepts. Taking into consideration the nature of product-service-systems, such reference models need to satisfy requirements derived from physical products (1), requirements taking into consideration the specific characteristics of services (2) and finally special modeling requirements dealing with the integration dimension of products and services (3).

While the use of such reference models in the area of product and service development is generally accepted, this research field regarding product-service systems is still in its infancy. Only five reference models dealing with integrated PSS could be found in the scope of a comprehensive literature review. Compared to the more universal reference models found in the manufacturing and service sector, most of these models involve specialized areas only, such as Quality Assurance or Facility Management [15]. Solely the reference model proposed by Abramovici et al. [7] deduced from ISO 10303 - also known as STEP standard (STandard for the Exchange of Product model data) - application protocol 214 [16], as well as the model proposed by Becker et al. [8] contemplate a more generalized view on PSS development. Yet, the model proposed by Abramovici still focuses on product information and neglects the special characteristics needed for designing services as well as the temporal development. On the other hand, the model proposed by Becker focuses more on services and the customers' willingness to pay for these services. Table 1 itemizes the existing reference models for PSS development.

Reference model	**Proposed by**	**Year**	**Source**
PSS Metadata Reference Model	Abramovici	2009	[7]
Language-based ServPay Model	Becker	2008	[8]
Quality Information System	Hoffmann	1999	[9]
Integrated Information Processing	Mertens	2001	[10]
Quality Information System	Schildheuer	1998	[11]

Table 1: Existing PSS Reference models listed by author, publication date and publication source

Hence, the development of such reference models needs to be pushed in order to provide practical and hands-on support for PSS providers.

B. *Need for sustainable integration of customer requirements into the solution design phase*

Development departments carry a heavy responsibility by determining product and service characteristics which affect human lives and company processes on a day-to-day basis [3]. That is why customer information has to be necessarily considered when designing new products and services. Within classical product development, the customer information generally is collected by asking questions regarding features and preferences of an already developed product as exemplified by Clausing [17] or Ulrich and Eppinger [18]. Enabling the integration of the customer information into a company's development processes as customer requirements, a three step procedure has to be followed. The designated steps include the Requirement Elicitation (1), the Requirements Analysis (2) and finally the Requirement Specification (3). Each step is supported by designated methods which include, for example: Kansei engineering [19], the Kawakita Jiro (KJ) method [20] or the Kano Model [21] for a psychology-based Requirements Elicitation; Conjoint Analysis [22], Analytical Hierarchical Processing (AHP) [23] or Fuzzy AHP [24] for Requirement Analysis; various modifications of Quality Function Deployment (QFD) [25] for Requirement Specification. The utilization of these methods is dependent to the purpose and context of use. A detailed state-of-the-art report regarding available methods dealing with customer requirements management can be found in [26]. Nevertheless, these methods restrict themselves to distinct points within product development solely with fixed milestones for customer incorporation. Continuous and steady customer integration is not envisioned as the effort for creation and analysis is all too time consuming. The more, a sustainable adjustment of the gathered requirements also beyond development processes spanning the whole lifecycle is not considered at all. Yet, due to an increase of market shifts in shorter periods of time, also the utilization phases of a product's and service's lifecycle have to be taken into consideration as both products and services need to be adjusted to changing market needs continuously.

These lacks prohibit an easy adoption of the methods for an integrated product-service development. Here, the customer as focal point has to be considered in a more holistic and profound way. That is why a sustainable integration exceeding the development processes and also regarding the usage phases as well as a continuous integration compared to punctual involvement has to be followed necessarily. Adequate process models for the development and provision of integrated solutions are under development for a couple of years as also emphasized in the previous chapter. Nevertheless, steps from customer analysis to solution engineering and provision are rather not viewed in detail within these process models, but seen as natural and thus given output of the cooperation [27]. If explicit methods for these steps are addressed, only existing methods from product development are touched on within the available process models. However, as customer information becomes more and more vital, additional effort within the field of academic product-service research for the continuous integration of customer requirements into PSS processes has to be provided. The target of this research is the provision of methods and technologies facilitating the handling of customer information in a structured and reusable manner. These methods need to enable a steadily customer requirements analysis also after the determination of the development processes.

C. *Need for transparent solution configuration*

It is the inherent claim of customer solutions to satisfy customer-specific necessities. In doing so, it is no longer the customers' duty to find the product most suitable for their desires. This task is passed over to the solution provider who needs to be able to understand the customers' necessities and provide the most suitable solution specification in a transparent fashion. Anyhow, conventional configuration approaches are not always directly understandable for the customer as they focus the manufacturers' natural viewpoint. According to prevalent literature, the product configuration describes the composition of a product from preset product components (so-called selection and combination) and the selection of specifications of the component properties (called parameterization) in accordance with the configuration rules [28][4]. This definition demonstrates that traditional product manufacturers presume the customer to have an extensive knowledge about the concerned area of expertise. Especially in business to customer (B2C) area, this assumption is associated with an intense examination effort for the affected customers. As a result, conventional product configurators exhibit a high termination rate due to conceptual gaps for supporting the customer in the decision-making process [28][5]. Although this gap is well known in industry, only few approaches dealing with this topic can be found.

Therefore, more customer-oriented approaches have to be developed, facilitating transparent processes for customer interaction. The customer needs to be able to express his needs and desires without necessarily having specialized product knowledge, enabling the direct expression of the customer's requirements. The subsequent translation of the customer statements into product characteristics then is task of the solution provider enabling a decrease of customer effort during the specification phase. The solution provider therefore needs to be able to handle the additional effort effectively. That is why non-supervised methods for the transformation of customer statements into product characteristics are needed which incorporate the natural fuzziness of customer information.

III. The Design for Customer Solution Approach

The approach presented in this paper builds upon the Product-Service Systems Engineering (PSSE) methodology proposed by Weber, Steinbach & Botta [29,30,31] as well as its continuation proposed by Thomas, Walter & Loos [32]. These methodologies represent the most comprehensive frameworks for integrated product-service systems development existing up to now. In particular, the 'Design for Customer' approach uses the distinction of structure-descriptive characteristics and behavior-descriptive properties postulated in both methodologies mentioned above. The distinction between characteristics and properties thereby is prescribed as follows: Characteristics define the PSS from a constructive point and may be determined directly by the developer. The properties of a PSS on the other hand describe the behavior of the products and services inherent in a PSS and may be influenced in an indirect way only. However, the properties are to be observed directly by a customer when using a PSS. Also, the properties constitute the actual needs and requirements of a customer in a customer-specific language.

Based upon the disjunction between properties and characteristics and in coherency with the outstanding research questions deduced in chapter 2, the following *research goals of the 'Design for Customer' approach* can be proposed:

- Provision of reference models for integrated product-

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service systems enabling a structured development and provision of PSS in a repeatable high quality. These information models need to be able to support existing and upcoming process models for PSS development.

• Provision of methods and tools for steady and continuous customer integration into PSS development processes using the natural process integration of the customer. The approach thereby focuses the specification and usage phase of product-service systems.

• Transparent and customer-centric solution configuration enabling the customer to articulate his necessities regarding a PSS without the need of having extensive expert-knowledge in the related area.

It is not the purpose of the present approach to replace the existing development methods postulated by Weber and Thomas. It may rather be seen as extension of both methods enabling a more comprehensive customer integration also covering the lifetime phases of a product-service system. In doing so, the approach highlights the customer integration in a more detailed and structured manner with the help of interrelated information models.

The approach is divided into four main pillars as also shown in Figure 1. These pillars include

• *The customer layer* enables the integration of the customer during the PSS specification and usage phase based upon a customer-driven solution configurator using the above mentioned properties

• *The PSS development layer* enables the knowledge representation of a PSS's characteristics in form of reference models as fundament for a structured development and provision of product-service systems

• The fuzzy-based rule set as *integration layer* between solution provider and customer enabling a translation between customer-specific properties and provider-specific characteristics

• *The feedback process stream* enabling the steady capturing and analysis of customer information and its direct feedback into the PSS development processes

The reference models mainly belong to the PSS development layer. However, due to their comprehensive nature they are displayed as discrete part of the solution approach within Figure 1. In the following chapters, the four main pillars will be illustrated in more detail. However, the focus of the present paper lies in the presentation of the fuzzy-based rule set depicted in chapter 3.3.

A. *Customer layer - Knowledge representation of the customer*

Within the first layer, the knowledge representation of the customer is determined. This layer includes the requirements

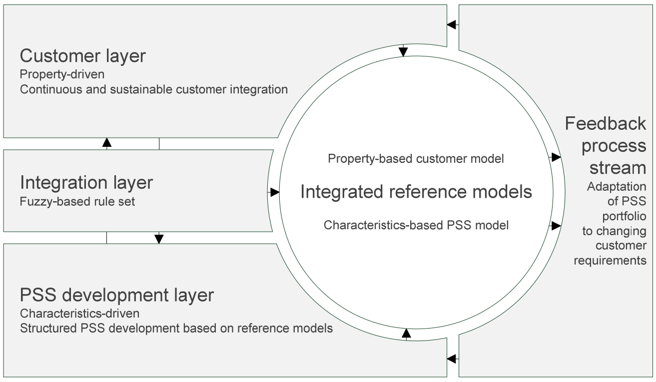

Figure 1: Conceptual Architecture of the Design for Customer Solution Approach

and business functionalities needed by the customer in order to satisfy his natural necessities and is thus not available in conventional approaches. The additional layer enables the customer to specify his needs without the definite knowledge of the provider's product and service portfolio and thus without specialized knowledge in the affected area. Thus, customer statements such as "I need assured mobility for at least 30 kilometers a day" become possible even without personal guidance by sales personal. The configuration of the appropriate product or service characteristics is then accomplished in the two layers described subsequently. The integration of the additional layer furthermore allows the customer not to make a commitment to a particular product or service right from the beginning. Instead, the most suitable option will be picked subsequent to his input. Thus, in the introduced example the configuration process may offer a pure product such as a car or an integrated product service system such as a car sharing. The representation of the customer layer occurs in an IT-based supported manner enabling the processing of mass data and its re-utilization for Customer Requirements Management.

As the content of this layer is highly individual and constitutes the company's very own core competencies, it needs to be developed by each PSS provider individually. Nevertheless, making this process manageable the associated classification model for PSS-properties may be used [30][6] [31][7] [33][8]. This model is defined as common classification system for both products and services [32][9]. The classification model thereby differentiates between searching properties, experience properties and trust properties.

Searching properties may be evaluated by the customer a priori. These properties reflect the basic and original necessities of a customer when searching and specifying the PSS. For example, such properties may contain aesthetic demands (the customer wants a modern and exclusive look of the car) or functional ones (the customer needs an assured

[6] page 548
[7] pages 77ff
[8] pages 138ff
[9] page 68

mobility for at least 30 kilometers a day).

Experience properties manifest themselves to the customer only when using the PSS. These properties comprise the de facto behavior of the acquired product-service system (for example the actual maintenance rate or the satisfaction with a functionality). Experience properties become vital if a change in the chosen PSS configuration becomes essential. Thus, a continuous adaption of a chosen configuration to changing customer requirements is possible.

Trust properties may not be evaluated directly by the customer. The customer may solely trust in the existence (for example a PSS's accordance with laws and norms). As a direct evaluation by the customer is impossible, their further consideration within the scope of the present approach is not required.

The searching properties constitute the interface to the customer during the configuration and specification phases on the one hand. During the usage phase of a solution on the other hand, the interface to the customer is defined by the experience properties. Thereby, the configuration of a PSS may alter over time enabling an adaption to a customer's changing necessities. Based upon the customer's decisions, the characteristics adequate to the selected properties may be chosen. This is done automatically using the fuzzy-based rule set described in paragraph 3.3. Yet, the knowledge representation of the PSS characteristics will be depicted in the following paragraph.

B. PSS development layer - Knowledge representation of integrated product-service development

The layer for integrated product-service development enables a structured development and provision of integrated product-service systems based upon an integrated reference model for both product and service development. Thus, the model forms the bodywork for the approach from constructive point of view, as the characteristics are manifest for both the offered products and services. Nevertheless, the reference model also builds upon the distinction between properties and characteristics as proposed by Weber and Thomas in order to support the present 'Design for Customer' approach in a formal way.

The model pays particular attention to the equal handling of product and service domain since major deficiencies within existing reference models can be found in this point. Aspects are incorporated from the existing more service-oriented approach proposed by Becker [8]. From a more product-oriented point of view, facets from the ISO 10303, application protocol AP 214 [16], and thus from Abramovici [7] are derived. Incorporated requirements include a modular design, consideration of temporal dynamics of customers' choices, interdisciplinary of the affected tasks and economic quantifiability. Particular attention was also paid to customer orientation which is fundamental for the present approach. Therefore, the model is divided into a generic model for

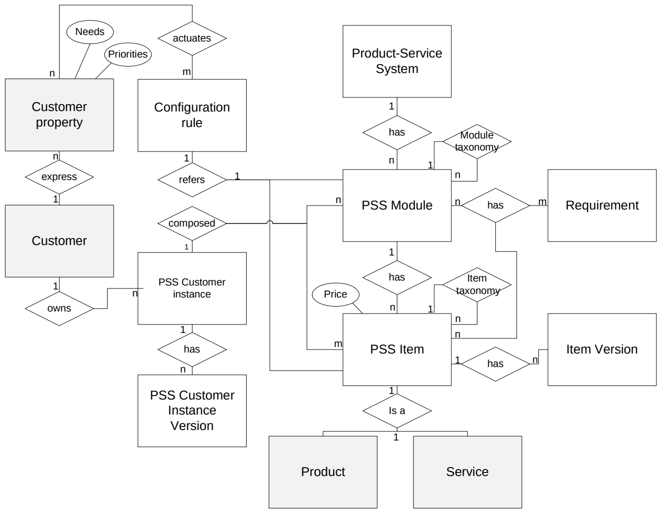

Figure 2: Core model of the applied reference model for integrated product-service development

general PSS development and a customer-specific model including the customer instance and the expressed properties. Formal requirements of the model include the system-oriented and system-independent representation, redundancy-free modeling, intuitiveness and scalability.

The model is designed using Entity Relationship Modeling (ERM); particularly the Chen-Notation [34] for ER modeling has been applied. Besides the core model shown in Figure 2, the model consists of four additional partial models for product development, service development, and two additional models for customer integration. However, the partial models will not be described in the scope of this paper.

Using the present model, a systematic and equal development and provision of both products and services is enabled. The model thereby provides the characteristics appropriate to the customers' properties. The interconnection between properties and characteristics is established using the fuzzy-based rule set postulated in the subsequent paragraph.

C. Integration layer - Fuzzy-based rule set supporting human uncertainty

An adequate model is needed for the interrelation of properties representing the customer's viewpoint on the one hand and the characteristics representing the viewpoint of the solution provider on the other hand. This model needs to support the following constraints:

Constraint 1: The model needs to support the handling of natural human fuzziness as customer statements are often vague and ambiguous.

Constraint 2: The interrelation between properties and characteristics needs to be transparent for both the customer and the solution provider.

Based upon these constraints, an analysis of established approaches for rule-based systems was carried out. As possible alternatives, Bayesian nets, Fuzzy systems and Neural nets where examined regarding their degree of performance against the debated constraints.

Bayesian nets follow the Bayesian probability theory and are therefore scientifically based on a unique axiom system. The nets are self-learning if logical values of distinct statements after becoming known successively. Anyway, a high degree of data processing capabilities are needed, as a large set of conditional probabilities needs to be determined. The more, implicit conditional independence is assumed and nescience may not be represented as the value of a thesis h is always 1 minus the value of its antithesis, or as formula: $P(h) = 1 - P(\neg h)$. For this reason, fuzziness related to human beings is not processable [35][10].

Fuzzy systems are expanding traditional Boolean logic to the continuum of grades of membership between 0 and 1 which makes them able to support fuzziness related to human beings [36]. They are storing their knowledge in a structured way in the form of rules so their functionality may be reconstructed intuitively. However, they are not directly self-adaptive which means that rules or fuzzy sets may not be generated from sample data automatically [37] [28].

Artificial Neural Networks are nets out of artificial neurons dedicated to have a learning ability similar to the neurocyte cross-linking of brain and spinal cord. In doing so, they are able to self-adapt from the scratch. Anyhow, the stored knowledge is unstructured and incomprehensible [28][11]. In many cases, a convergence of functions dependent on their input data is not observable or to a minor degree only [37][12]. For the present use case, neural nets consisting of one input layer and one output layer would be needed which makes them too labor-intensive to apply.

Based on this analysis, a Fuzzy system was chosen for the interrelation of the customer-driven properties and the provider-driven characteristics. The Fuzzy process model thereby comprehends five process steps enabling the transformation of the fuzzy-based rule set into mathematical functions. The five steps of the Fuzzy process model imply (1) the fuzzification of the properties using membership functions, (2) the aggregation discrete properties allegorized by the Fuzzy-And-connection within the premise, (3) the implication using an adequate implication operator, (4) the accumulation of the different rules being addressed and (5) the defuzzification resulting in unique output parameters. Using the emerging mathematical output parameters, the adequate PSS characteristics may be interrelated to the properties given as input by a customer in a quantitative manner. In the following, the five process steps will be depicted in more detail.

At first, the necessary variables declarations will be accomplished. Thereby, the customer properties are declared as N-dimensional Fuzzy-vector

$$\mathcal{P} = (\mathcal{P}_1, \mathcal{P}_2, \dots \mathcal{P}_n) \quad (1)$$

within the vector space $\mathcal{V} = \mathcal{V}_1 \times \mathcal{V}_2 \times \dots \times \mathcal{V}_n$ with $\times$ representing the Cartesian product operator. The universe of discourse of $\mathcal{V}$ is given by natural human statements. For example, a model variable $\mathcal{P}_i$ can be declared as *„Aesthetic Design"* of a car. Then, the customer-specific property vector with the chosen properties is

$$\wp = (\wp_1, \wp_2, \dots \wp_n) \quad (2)$$

Furthermore, the properties are assessed by the customer using a predefined set of linguistic variables representing the customer's rating of property $\wp_i$. For each property, linguistic values $\mathcal{LW}_{i,j}$ are defined as follows: There are q linguistic values $\mathcal{LW}_{i,j}$ for each customer property $\wp_i$ with $j = 1,2,\dots,q$.

The linguistic values $\mathcal{LW}_{i,j}$ in connection with a customer's property $\wp_i$ are forming facts $\wp_i \curvearrowright \mathcal{LW}_{i,j}$ which express the customer's mindset related to the property $\wp_i$.

The characteristics are defining the PSS from a constructive point and directly determined by the developer. They are defined in analogy to the customer properties. The characteristics of a PSS are an M-dimensional Fuzzy-vector

$$\mathcal{C} = (\mathcal{C}_1, \mathcal{C}_2, \dots \mathcal{C}_m) \quad (3)$$

within the vector space $\mathcal{W} = \mathcal{W}_1 \times \mathcal{W}_2 \times \dots \times \mathcal{W}_m$, with $\times$ representing the Cartesian product operator. For each model variable $\mathcal{C}_i$ there is an actual characteristics variable c_i representing the PSS characteristics associated to the customer's properties $\wp = (\wp_1, \wp_2, \dots \wp_n)$. The customer-specific characteristics value then is

$$c = (c_1, c_2, \dots c_m) \quad (4)$$

In analogy to the customer properties, linguistic variables $\mathcal{LV}_{i,j}$ for each PSS characteristic c_i with $j = 1,2,\dots,r$ are defined enabling facts in the form $c_i \curvearrowright \mathcal{LV}_{i,j}$.

This enables the creation of a fuzzy-based rule set consisting of rules $\mathcal{R}_k$ $(k = 1,2,\dots,s)$. A general fuzzy rule $\mathcal{R}_k$ relating to a number of customer properties $\wp_i$ with linguistic variables $\mathcal{LW}_{i,j}$ $(j = 1,2,\dots,q)$ to product characteristics c_i with linguistic variables $\mathcal{LV}_{i,j}$ $(j = 1,2 \dots,r)$ can be expressed as:

[10] pages 48ff
[11] pages 168-176
[12] pages 131ff

$$\mathcal{R}_k: If\ \ p_1\ is\ \ \mathcal{LW}_{1,1}, and\ p_2\ is\ \ \mathcal{LW}_{2,2}, and\ ...\ ...\ p_n\ is\ \ \mathcal{LW}_{n,n}\ then\ c_i\ is\ \mathcal{LV}_{i,j} \quad (5)$$

Fuzzification

For each fact $p_i = \mathcal{LW}_{i,j}$ chosen by the customer there are membership functions $\mathcal{A}_i$ assigning membership values $\mu_{\mathcal{LW}_{i,j}}$ to each linguistic variable $\mathcal{LW}_{i,j}$ belonging to a customer property p_i. A mapping relation $\mathcal{A}_i$ is defined as

$$\mathcal{A}_i = \left(\mu_{\mathcal{LW}_{i,1}}, \mu_{\mathcal{LW}_{i,2}}, ... \ \mu_{\mathcal{LW}_{i,q}} \right) \ (i = 1,2, ..., N) \quad (6)$$

whereby $\mu_{\mathcal{LW}_{i,j}}\ (j = 1,2, ..., q) \ \in \mathbb{R}$ is from the interval [0,1]. $\mu_{\mathcal{LW}_{i,j}}$ represents the safety degree of the Fuzzy set p_i.

Aggregation

The aggregation represents the Fuzzy-And-connection within the premise of a Fuzzy-rule $\mathcal{R}_k$. The value $\mu_{agg,k}(p_1, p_2, ... p_n)$ is the result of the premise of a rule $\mathcal{R}_k$, which means the If-Part of the Fuzzy-Implication. Choosing the Minimum-Operator as possible alternative for the aggregation's AND-operation, $\mu_{agg,k}(p_1, p_2, ... p_n)$ results in:

$$\mu_{agg,k}(p_1, p_2, ... p_n) = \min \{\mathcal{A}_i, \mathcal{A}_2, ..., \mathcal{A}_n\} = \min \{ \mu_{\mathcal{LW}_{1,1}}(p_1), ..., \mu_{\mathcal{LW}_{n,q}}(p_n)\} \quad (7)$$

Implication

The value $\mu_{agg,k}(p_1, p_2, ... p_n)$ needs to be connected to the membership function $\mu_{\mathcal{LV}_{i,\ell}}(c_i)\ (i = 1,2, ..., M)$ related to the PSS characteristic c_i using an adequate Implication-Operator whereby $\mu_{\mathcal{LW}_i}(c_i) \in \mathbb{R}$ is from the interval [0,1] and represents the safety degree of the Fuzzy set regarding c_i.

As a result, the premise of a rule $\mathcal{R}_k$ (containing the customer properties) and the conclusion of this rule (containing the PSS characteristics) are interconnected. Using the Minimum-Operator for the Implication, then a rule R_k for characteristic c_i results in

$$\mu_{k,c_i}(p_1, p_2, ... p_n, c_i) = \min \{ \mu_{agg,k}(p_1, p_2, ... p_n), \mu_{\mathcal{LV}_{i,\ell}}(c_i)\} \quad (8)$$

Accumulation

The interconnection of all k rules, respectively their implication results $\mu_{k,c_i}(p_1, p_2, ... p_n, c_i)$, occurs by means of an Or-Interconnection. In the present approach, the Max-Operator was chosen. As result, we get:

$$\mu_{akk,c_i}(p_1, p_2, ... p_n, c_i) = \max\{ \mu_1(p_1, p_2, ... p_n, c_i), ..., \mu_k(p_1, p_2, ... p_n, c_i)\} \quad (9)$$

The membership function μ_{akk,c_i} represents the result of the evaluation of all rules dependent on the PSS characteristic c_i. In general, the membership function delivers a measurement for the rule base's output value c_i, which is not utilizable immediately.

Defuzzification

In order to obtain a unique assignment of the input variables $c_1, c_2, ... c_n$ to the output variable p_i, the resulting outcome μ_{akk,p_i} of the accumulation in the form of a surface area yet needs to be defuzzificated. If all contents of $\mu_{akk,c_i}(p_1, p_2, ... p_n, c_i)$ need to be integrated, then - for the averaging of all rule results – the method for the calculation of the center of area (COA) has to be chosen. This value is calculated as follows:

$$c_{i,res} = \frac{\int c * \ c_i\,(c) dc}{\int c_i\,(c) dc} = \frac{\int c * \ \mu_{akk,c_i}(p_1, p_2, ... p_n, c_i)\ dc}{\int \mu_{akk,c_i}(p, p_2, ... p_n, c_i)\ dc} \quad (10)$$

with $c_{i,res} \in \mathbb{R}$ from the interval [0,1]. The variable $c_{i,res}$ describes the membership of the PSS characteristic c_i to the properties $p = (p_1, p_2, ... p_n)$ entered by the customer. The higher the value of $c_{i,res}$, the higher product characteristic c_i is intercorrelated with the customer's properties.

Thus, an interconnection between customer properties representing the customers' primary necessities and the PSS provider's product and service characteristics was established. The interconnection considers natural human fuzziness and delivers quantitative values for the degree of membership between properties and characteristics. Based on these quantitative values, a configuration offer adequate to the customer's requirements may be submitted by the PSS configurator.

D. *Feedback process stream – Adaptation of PSS portfolio to changing customer requirements*

Being able to absorb and store customer knowledge in a formal way using information technology facilitates its re-utilization in affiliated processes of the solution provider. In particular, the customer knowledge may serve as input for a more customer-oriented product and service development, enabling a direct responding to the customers' changing needs. Using both the customers' property information and the PSS characteristics information, continuous non-supervised requirements analyses may be carried out. The analyses represent delta analyses matching the elicited As-Is status with the To-Be-status. Encountering sufficient support or critical mass for a particular delta, Engineering Change Requests (ECR) are created by the system automatically. These Engineering Change Requests constitute working instructions including the component accountable for the delta. Thereby, a distinction between several use cases becomes necessary.

In the first case, the analyses may discover major discrepancies originating within the customers' searching properties. In general, this case determines if the solution provider covers all customer or market trends within his portfolio. Three subcategories may be differentiated:

Case 1.1: The customer chooses the characteristics according to his entered properties offered by the system. No action is required, since As-Is and To-Be status are conform with each other.

Case 1.2: The customer chooses different characteristics as proposed by the system. The reason for an incorrect property-characteristic-interrelation either may lie within an incorrect mapping entered into the system or within changing customer requirements. In the latter case, this trend becomes noticeable very gradually. Exemplary, more and more customers will buy electric cars instead of energy-saving petrol-driven cars when entering the property "environmental impact is important".

Case 1.3: No characteristics mapped to the entered properties are found. Encountering sufficient support, this status indicates that a customer trend is not incorporated within the solution provider's product and service portfolio.

In the second case, the analyses may discover major discrepancies originating within the customers' experience properties. Deflections within this case generally may discover quality deficiencies as well as changing customer needs.

Case 2.1: Customer satisfaction for the acquired products and services is above or in line with the customer's expectations. No action is required, since As-Is and To-Be status are conform with each other.

Case 2.2: Customer satisfaction for the acquired products and services is insufficient. This may be due to low quality of the offered products and services or due to changing customer needs. In both cases, alternative solution configurations may be proposed and adequate actions need to be performed improving the quality of the affected PSS items.

The analyses are carried out using existing technologies from 'Knowledge Discovery in Databases'. In particular, association analyses as well as cluster analyses can be used. Association analyses thereby analyze the interrelations between elements of the existing data sets. Common technologies include the A-priori algorithm or its extension the A-prioriH algorithm enabling the usage of item taxonomies [38]. Cluster analyses on the other hand are used for subsuming data sets into groups using affinity concepts. Thereby, hierarchical methods being either agglomerative or divisive are applied such as the single-linkage clustering or the k-nearest-neighbor heuristic. The more, algorithms using an iterative partitioning such as the k- means algorithm are utilizable for the present approach [38] [39].

The determination of the appropriate support vector for the activation of an Engineering Change Request is highly company-dependent. Likewise, the responsible departments (product development, service development, marketing, sales) proper for each single case need to be defined company-specific. Methods for the synthesis of the analyzed customer requirements into new or ameliorated products and services are provided by the process models proposed by Weber [9] and Thomas [10].

IV. Conclusion

Substantial progress has been achieved in the areas of product-service provision over the last years. However, substantial deficiencies still can be found in the areas of integrated product-service-development and customer integration. The present paper highlights these deficiencies and proposes a concept for continuous customer integration using a novel configuration approach based on the distinction of properties and characteristics. Using the elicited customer information as trigger for product and service development, a constant adjustment of the offered product and service portfolio according to changing customers' requirements can be carried out. The expansion of the introduced approach using semantic technologies enabling a more holistic elicitation of customer knowledge yet is a future research step.

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