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SIMILARITY-BASED CONCEPT DEVELOPMENT FOR MODULAR PLATFORM SYSTEMS

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ABSTRACT

Today's companies are facing the challenge of managing high product variety due to increasing customer demands. This challenge results in a change of product development processes. Platforms and modular strategies are introduced as an approach to deal with increasing product variety. With optimal planning of platform designs and modular systems the effort in dealing with the complexity of multiple product variants can be significantly reduced.

This paper presents a methodological approach aimed at supporting the decision making process in the conceptual phase for the development of new product variants. Based on selected characteristic attributes of product or part variants, a similarity index that allows quantitative comparison of different variants from different modular platforms can be calculated. The main purpose of this method is to derive a clear recommendation regarding the development method of new product variants based on their degree of similarity. The method proposed in this paper can be used for conceptual planning of product, part or assembly variants in all industry areas, such as automotive industry, aircraft industry, or machinery and plant manufacturing industry.

Keywords: complexity, conceptual design, platform strategies, product variant, modular systems

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1 INTRODUCTION

The challenges that companies in recent years are facing have increased dramatically. This resulted mainly from the continuous changes of market situations due to globalization and its effect on international competitions, shortened product lifecycles, as well as rapidly advancing technologies (Simpson et al., 2006). Furthermore, increasing customer demands for high option variety add up to the requirements, which companies and their products and processes have to fulfill.

Nowadays companies cannot afford to ignore the customer needs for personalized products and high option variety in order to stay competitive. On the other hand, the increasing number of product variants means more complexity in product development processes. Balancing the external and internal variety as well as trade-off between diversification and standardization is the key factor that determines the success for a company (Robertson and Ulrich, 1998).

For the purpose of managing a high number of product variants while keeping the variety of parts and assemblies within the company on a moderate level, platform approaches and modular designs are introduced as methods to support standardization and reuse of components within and across different product families. With this strategy, scale effects can be achieved, which, in turn, reduce production costs and lead time in the development process of product variants (Daniilidis et al., 2011).

Based on standardized modular platforms, we discuss in this paper the similarity aspect between the derived product or part variants of a platform and present a conceptual approach to support the decision making process regarding the development of new product variants using modular platforms as design foundation.

2 STATE OF THE ART

2.1 Flexible Platform through Module-Based Approach

The choice of product architecture, which is defined by Ulrich (1995) as the arrangement of functional elements, the mapping from functional elements to physical components, and the specification of interfaces between physical components, determines to a large extent how the requirements for realizing high external product variety can be met, while still minimizing additional costs incurred due to internal complexity. In case of establishing new variants by means of product modification, the product architecture defines which parts or functions of the product are affected. As product architecture also influences the flexibility of variants in terms of part or function exchange, the desired range of variants in a product family must be considered during the process of defining the product architectures (Cornet, 2002).

Simpson et al. (2006) show several approaches to design a product family. In a top-down approach, a product family is developed based on a standard platform and its derivatives, whereas the bottom-up approach is based on standardization of components from a consolidated group of distinct products. The most remarkable approach however, is a module-based approach, in which new product family members are generated by adding, substituting, and/or removing one or more functional modules from the platform, thus increasing the flexibility of the platform.

This approach is defined in this paper as modular platform or module-based platform. The modules, as defined in Pahl et al. (2007), can be seen as building blocks, which can take the shape of parts, assemblies, or machines. These modules can be built as separable and/or inseparable units and can include size ranges. They can also be differentiated between function modules, which help to implement technical functions, and production modules, which are based on assembly constraints. Through the combination of modules with the help of the architecture, which specifies what modules belong to the product and what functions they fulfill, and the interfaces, which describe how the modules interact with each other (Baldwin and Clark, 1997), a variety of overall functions can be fulfilled.

By using the modular platform strategy, it is possible to move from a rather closed architecture, which is often found in automobile products (Muffatto, 1999), to a more open product architecture. Through the combination of standardized components of a platform that allow part commonality, hence economies of scales, and the flexibility of modular building blocks, a high option variety can be achieved while still maintaining the distinctiveness between different product families (Figure 1).

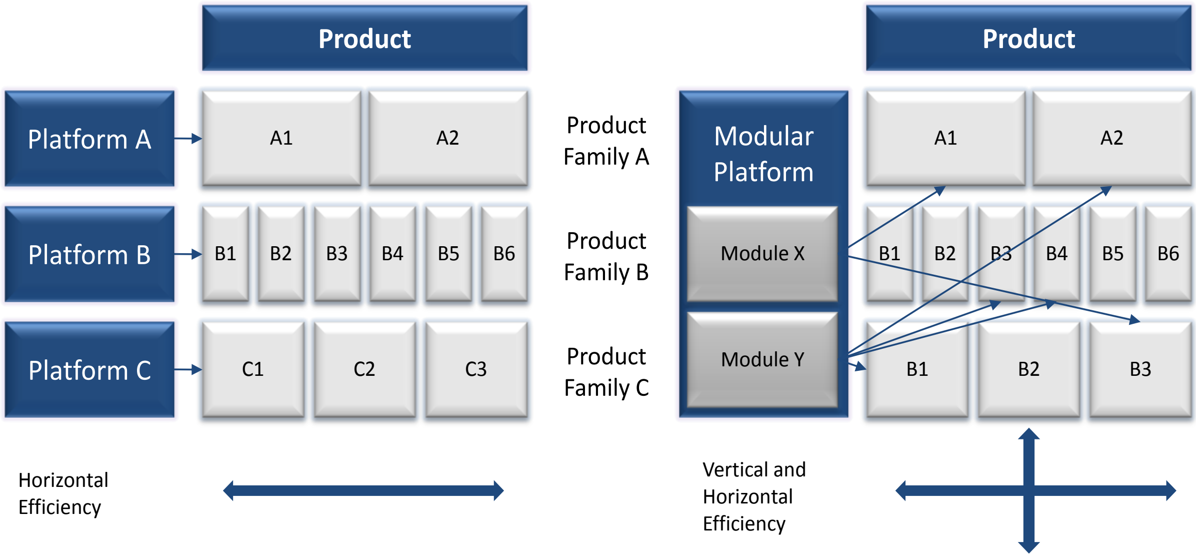

Figure 1. Comparison of standard platforms and module-based platforms (Hüttenrauch and Baum, 2008)

2.2 Planning of Modular Product Platforms

Muffatto (1999) listed some of the major problems that arise in the decision making process during platform development. The decision problems include among other things the expansion or reduction of platforms and its derivatives, the integration of existing platforms, the development of new platforms, and also the cross transfer of platforms between variants.

As the main objective of modular platform design is to use synergies from part commonality and therefore raising economies of scales by sharing and reusing modules in different products, the optimal result of platform strategies can only be achieved if the platform is used in different product families and several generations of a product variant (Muffatto, 1999; Schenkl et al. 2011). To achieve this result, future product variants that should be derived from a platform as well as the lifecycle of these derivatives of the platform and the platform itself have to be considered during the planning and development process of the platform and its modules. Furthermore, to ensure the flexibility of the modular platform, the adaptability of the modules and how the platform evolves during its lifecycles must also be taken into account.

A wide range of approaches for platform development exists in the literature. However, the most commonly used approach so far has been to derive platforms from existing product variety and then develop future product variants from those platforms (Muffatto, 1999). This was shown, for example, in Schenkl et al. (2011), which takes the approach of using product portfolio as the basis for the definition of new platforms. The platforms are derived based on the analysis, whether different components of existing products can be merged into a platform. The derived platforms and the possible derivatives define the platform portfolio, which then determines future product variants.

Another approach to develop modular platform systems is presented by Dai and Scott (2007), who developed a model to design product platforms using sensitivity and cluster analysis. There is also the approach by Kohlhase and Birkhofer (1996), who differentiated between the task of planning the modular system, developing the modular structure, and actually designing the model.

The methodological approaches described in the literature are indeed useful to design a modular platform and its derivatives from an existing product variety. However, the adaptation of the platform in its entirety has to be ensured, as product updates, new product generations or new products may require an update of a platform, new generation of a platform, or even a new platform (Muffatto, 1999; Schenkl et al. 2011). Also there is the risk of lack of distinctiveness between different product variants that are derived from the same platform, which can cause performance loss in meeting customer demands.

3 RESEARCH CHALLENGES

As explained in the previous section, most of the approaches in the literature only deal with the development of modules and platforms from an existing product portfolio with the intent to derive new

product variants from the developed platforms. However, it is also possible to perform the conceptual planning of a new product variant independently of existing platforms in the first step, and then look into the available platforms to determine, which of the existing platforms is more suitable to develop the planned product variant, or which modules of the platforms can be used in the new variant. The benefit of this approach is that the designer can be more creative during the conceptual phase of the process of planning new product variants and that the specifications of this new variant are not strictly constrained by the specifications of the existing platforms, thus allow more innovation and ensure the distinctiveness of the new product.
Consequently, if a variant should be developed using the modular platform as design foundation and several platforms exist in the company, a decision has to be made regarding the best choice of the platform. For this purpose, this paper aims to deliver an answer for the following problems:

- What kind of methodologies and approaches exist regarding the planning and development methods of a new product variant and how can the decision be made?
- If several modular platforms exist, to which should a new product variant be assigned?
- What impact does a new product variant have on the modular system and how does the modular system evolve during its lifecycle?

4 CONCEPT

In this paper, a concept is developed as a decision support method for lifecycle accompanied planning of new variants of modular platform. This concept is divided in three steps as follows:

1. Identifying the basic assumptions needed for the development of new product variants.
2. Establishing a similarity index as foundation for the decision.
3. Gathering the conditions for the decision making process and deriving a recommendation based on a decision tree.

Each of the steps will be further explained in the following sections. To achieve a better understanding of the concept and to verify the concept, an example will be given afterwards.

4.1 Basic Assumptions

This concept is based on the assumption that one or more modular platforms already exist. Hence, a couple of requirements have to be proposed for the existing modular development process to ensure the success of the modular platform.
First, we assume that a number of modular platforms $PF = \{PF_A, PF_B, PF_C, \dots\}$ and a number of product variants $PV = \{PV_1^{PF}, PV_2^{PF}, PV_3^{PF}, \dots\}$, which are derived from each platform, exist in the company. Furthermore, it is assumed that the compatibility of the interfaces between modular parts of different product variants in a platform is guaranteed.
For each modular platform, the characteristic attributes that are essential to classify the product variants and to distinguish the platforms from each other have to be defined. For example, in an engine platform the possible characteristic attributes might be the number or diameter of cylinders. Because the characteristic attributes are later used to calculate the degree of similarity between different product variants, it is important that they are quantifiable.
All characteristic attributes have then to be weighted accordingly. The choice of the weighting factor of each attribute should represent the influence of the attribute on the composition of the modular platform. Furthermore, the weighting factor should reflect its costs impact and the necessary effort for the adjustment of the modular platform.
Finally, the values of all characteristic attributes are then gathered for each of the product variants. Because the characteristic attributes can be of very different dimensions, it is important to normalize the attribute values accordingly, hence creating dimensionless variables. This ensures that the calculation includes no distortion or bias. In this paper, we choose a min-max-normalization because of the assumption that a platform has constraints regarding the maximum and minimum values of its attributes that it can fulfill. This normalization is shown in Equation (1), in which x represents the original attribute value and x^* the normalized value that should vary between 0 and 1. The normalized attribute values of each product variant will then provide the basis for the calculation of the similarity index.

$$x^* = \frac{x^*_{max} - x^*_{min}}{x_{max} - x_{min}} (x - x_{min}) + x^*_{min} \tag{1}$$

4.2 Calculating the Similarity Index

The foundation of the proposed concept is provided by cluster analysis. In this case, we imagine a multidimensional coordinate system, whose axes are given by the characteristic attributes. Each product variant is projected as a point in this coordinate system that represents the combinations of the attribute values. A platform is then illustrated as a cluster of similar product variants. As the product variants that are derived from the same platform should have similar attributes, they should be nearby each other. Likewise, the product variants of the same platform should be more similar to each other than they are to the derivatives from other platform (Figure 2).

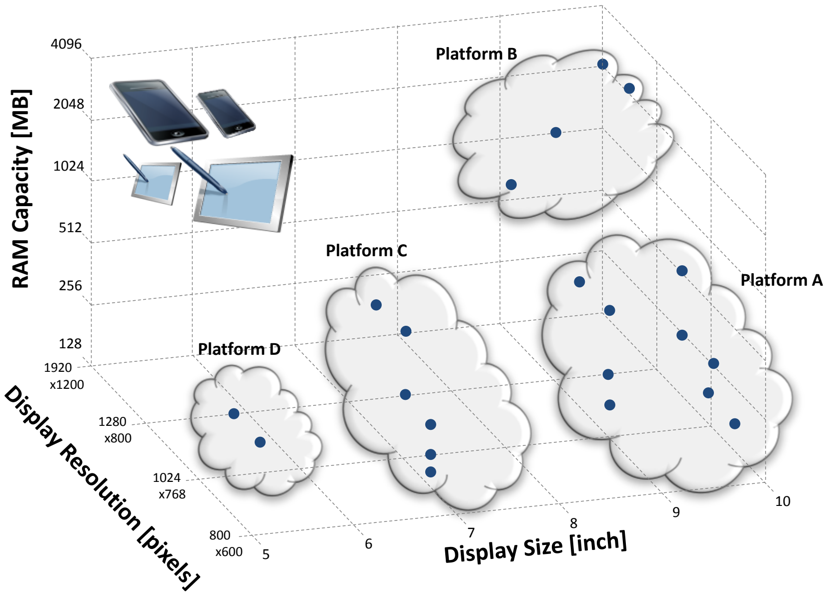

Figure 2. Illustration of clustered platforms for tablet PC in a 3D coordinate system

For each cluster that represents a modular platform, the average value M_i of every characteristic attribute must be calculated. The center point (CP) of a clustered platform can be determined through the combination of the average values in the coordinate system. This point represents the theoretical archetype of a modular platform and is in the center of all corresponding objects in a cluster.

The degree of similarity of the characteristic attributes between two objects in a coordinate system is inversely related to the distance between these objects. Consequently, the degree of similarity between different product variants can be calculated using weighted Euclidean distance, which is shown in the following equations.

$$d_{jk}^{PF} = \sqrt{\sum_{i=1}^{p} \lambda_i (x_{ij}^{PF} - x_{ik}^{PF})^2} \quad (2)$$

$$d_{Mj}^{PF} = \sqrt{\sum_{i=1}^{p} \lambda_i (x_{ij}^{PF} - M_i^{PF})^2} \quad (3)$$

The Equation (2) shows the weighted Euclidean distance d_{jk}^{PF} between two product variants j and k of the same platform, whereas the Equation (3) shows the weighted Euclidean distance d_{Mj}^{PF} between a product variant j and the center point of a platform, which represents the archetype object. The variable x_{ij}^{PF} here represents the value of the characteristic attribute i of the product variant j with λ_i as the weighting factor of the attribute i.

Using the largest distance between the product variants in a platform and the center point of the platform, the similarity range of a platform can be derived. By calculating the Euclidean distance to the center point of the platform, the similarity radius of the platform can be determined, which at the same time represents the adaptability of the modular platform system. From the weighted Euclidean distance, the similarity index SI can be derived by inverting the Euclidean distance in ratio to the maximum allowed distance d_{max}, as shown in Equation (4) and (5).

$$SI_{jk}^{PF} = 1 - \frac{d_{jk}^{PF}}{2 d_{max}^{PF}} \quad (4)$$

$$SI_{Mj}^{PF} = 1 - \frac{d_{Mj}^{PF}}{d_{max}^{PF}} \quad (5)$$

For this step, it is required that the maximum allowed distance, which is measured from the center point of the platform, is defined. This maximum allowed distance represents the theoretical radius of a modular platform cluster. For this reason, the value of d_{max} should be at least as high as the distance between the center point and the farthest product variant to ensure that the platform cluster includes all corresponding product variants as its derivatives. Furthermore, the calculation of d_{max} should include the largest deviation to the average value of each characteristic attribute. The maximum allowed distance can thus be calculated with following equation.

$$d_{max}^{PF} = \sqrt{\sum_{i=1}^{p} \lambda_i (max_j\{|x_{ij}^{PF} - M_i^{PF}|\})^2} \quad (6)$$

The values of the Euclidean distance and the similarity index are then gathered in the distance matrix and similarity index matrix accordingly (Figure 3).

Distance Matrix

	PV₁	PV₂	PV₃	...	PVₖ
PV₁	d_{11}	d_{12}	d_{13}	...	d_{1k}
PV₂	d_{21}	d_{22}	d_{23}	...	d_{2k}
PV₃	d_{31}	d_{32}	d_{33}	...	d_{3k}
...	...	...	...		...
PVⱼ	d_{j1}	d_{j2}	d_{j3}	...	d_{jk}
CP	$\mathbf{d_{M1}}$	$\mathbf{d_{M2}}$	$\mathbf{d_{M3}}$	**...**	$\mathbf{d_{Mk}}$

Similarity Index Matrix

	PV₁	PV₂	PV₃	...	PVₖ
PV₁	SI_{11}	SI_{12}	SI_{13}	...	SI_{1k}
PV₂	SI_{21}	SI_{22}	SI_{23}	...	SI_{2k}
PV₃	SI_{31}	SI_{32}	SI_{33}	...	SI_{3k}
...	...	...	...		...
PVⱼ	SI_{j1}	SI_{j2}	SI_{j3}	...	SI_{jk}
CP	$\mathbf{SI_{M1}}$	$\mathbf{SI_{M2}}$	$\mathbf{SI_{M3}}$	**...**	$\mathbf{SI_{Mk}}$

Figure 3. Distance and similarity index matrix

4.3 Planning New Variants

If a company wants to create a new product variant, it could choose to develop the new product individually or to use the existing modular platforms as foundation for the product development. For the latter, the similarity between the planned product and the existing platforms has to be analyzed. In case neither of the platforms, which exist in the company, fits the requirement for the development of the new product variant, either an existing platform has to be adjusted or the company can decide to generate a new platform to develop the planned product.

To assist the conceptual decision making process in selecting the appropriate method for the development of a new product variant, a guideline that supports the decision making based on the degree of similarity of the proposed variant is designed as the main focus of this paper. A policy recommendation is then derived from the guideline, which should fulfill the conditions imposed in the guideline.

The decision tree for planning a new product variant is shown in Figure 4. As the first step, the values and the weighting factors of the characteristic attributes of the proposed new variant have to be determined. Using these attribute values, the weighted Euclidean distance and the similarity index between this new variant and the center point of each platform as well as the existing product variants of the corresponding platforms can be calculated. In the next steps, the decision tree will be analyzed from top to bottom and the requirements will be examined properly.

4.3.1 Case (1)

The first question asked is whether the planned new product variant can be incorporated into an existing platform without making any adjustment to the respective platform. To develop the new product variant using an existing platform, the weighted Euclidean distance between the new product variant and the center point of the platform must be smaller than the distance between the center point and the farthest product variant in the platform (Decision 1).

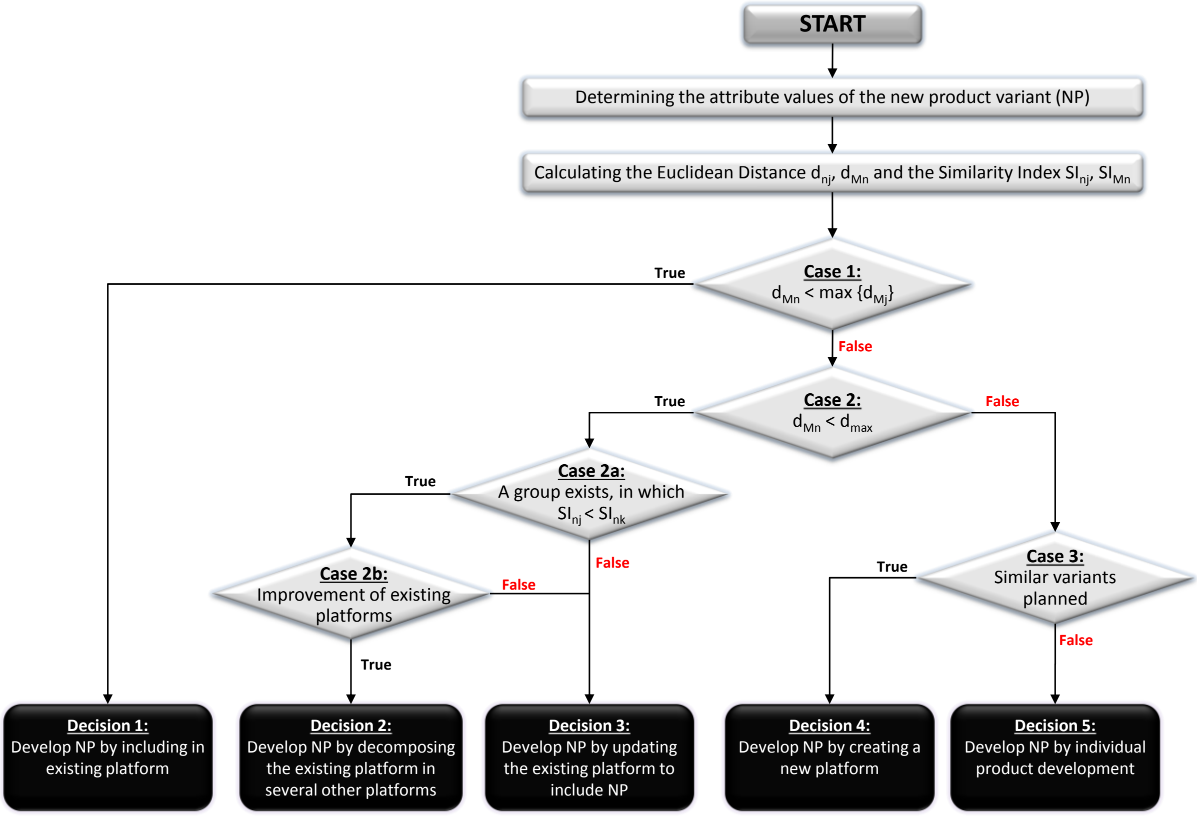

Figure 4. Decision tree to support new product variant development

4.3.2 Case (2)

If the first condition is not fulfilled, the next step is to analyze, whether one of the existing platforms can be considered for an adjustment to include the new product variant. The condition is that the Euclidean distance between the new variant and the center point of the examined platform must be smaller than the maximum allowed distance. If this condition is met for one of the existing platforms, then further examination has to be performed for the corresponding platform in order to decide, whether an update of the considered platform would be useful (Decision 3) or whether it would be better for the platform to be divided into several other platforms (Decision 2). For this purpose, two additional requirements (Case 2a-2b) are presented in order to make a decision.

4.3.3 Case (2a)

The decision to split the existing platform into several other platforms can be made by answering the question, whether a smaller cluster of product variants within a platform exists, which has a higher degree of similarity to the planned product variant. This can be recognized through the similarity index or the weighted Euclidean distance between the new product variant and the existing variants of the platform. The objective of this case is to answer the question, whether a decomposition of the platform into smaller clusters that consist of several product variants with higher similarity is possible. If this condition is fulfilled, then the next condition has to be analyzed.

4.3.4 Case (2b)

By dividing a platform into several other platforms, new clustered platforms are created. Each of these newly formed platforms has different compositions and therefore new center points, which influence the range of the platforms and thus the degree of similarity between the objects in a platform.

Due to the partition of the platform, additional expenses or adjustment costs might occur. Therefore, it should be evaluated, whether the benefits from the partition of the platform justify the additional costs that arise to develop and manage the new platforms. As the partition of the platform should not have any negative effects to the overall result, the partition of the platform will only be carried out, if the benefit outweighs the expenses from splitting the platform. The comparison of the similarity range, which is derived from the weighted Euclidean distance between the farthest object and the center

point, can be used, for instance, as the foundation for the decision. In this case, the similarity range of the newly formed platforms should not exceed the similarity range of the original platform.
If one or both conditions (Case 2a-2b) are not satisfied, then none of the platforms should be decomposed. Instead, the considered platform, for which the condition proposed in Case 2 is fulfilled, should be updated in order to include the new product variant (Decision 3). It is thinkable, that there might be several constructions possible, in which the condition is met. In this case, the similarity index and the maximum allowed distance can form a basis for decision making. In the end, the platform which has a higher degree of similarity to the new planned product variant should be chosen.

4.3.5 Case (3)

The last condition is used to determine, whether the new product variant should be entirely developed through an individual new product development or whether a new modular platform, which includes the planned variant, should be built. The decision can be made by analyzing the future product roadmap. In the event of similar future variants planned, it might be advantageous if a new platform is created with the specifications of the currently proposed product variant for an early anticipation of the development of future similar products (Decision 4). If the proposed product variant is unique, however, or covers a specific niche segment, for which no other products are planned in the future, there is no reason to make an effort in creating a new platform. Hence, the new variant should be developed by an individual product development (Decision 5).

5 USE-CASE

To validate the methodological approach proposed in this paper, a testing case is implemented based on real products from automotive industry. Our system consists of two modular platforms (PF-A and PF-B) and each of them consists of six vehicles as product variants. The defined characteristic attributes include both geometrical attributes, such as length, width, and height of the vehicles, and performance attributes, such as top speed, cylinder capacity, and peak engine power. After gathering the attribute values for each product variant, as well as determining the weighting factors for each characteristic attribute, the weighted Euclidean distances and the similarity indexes are calculated. The results are shown in Figure 5.

Distance Matrix of Platform PF-A

d_{jk}	PV^A_1	PV^A_2	PV^A_3	PV^A_4	PV^A_5	PV^A_6
PV^A_1		0.16	1.24	1.22	1.34	1.47
PV^A_2	0.16		1.24	1.24	1.33	1.45
PV^A_3	1.24	1.24		0.28	0.80	1.23
PV^A_4	1.22	1.24	0.28		0.80	1.26
PV^A_5	1.34	1.33	0.80	0.80		0.89
PV^A_6	1.47	1.45	1.23	1.26	0.89	
CP^A	**0.80**	**0.79**	**0.59**	**0.60**	**0.64**	**0.91**

Similarity Index Matrix of Platform PF-A

SI_{jk}	PV^A_1	PV^A_2	PV^A_3	PV^A_4	PV^A_5	PV^A_6
PV^A_1		93%	48%	49%	44%	38%
PV^A_2	93%		48%	48%	44%	39%
PV^A_3	48%	48%		88%	66%	48%
PV^A_4	49%	48%	88%		66%	47%
PV^A_5	44%	44%	66%	66%		63%
PV^A_6	38%	39%	48%	47%	63%	
CP^A	**33%**	**34%**	**50%**	**50%**	**47%**	**24%**

Distance Matrix of Platform PF-B

d_{jk}	PV^B_1	PV^B_2	PV^B_3	PV^B_4	PV^B_5	PV^B_6
PV^B_1		0.33	1.74	1.79	1.85	1.70
PV^B_2	0.33		1.74	1.79	1.83	1.75
PV^B_3	1.74	1.74		0.39	0.61	1.41
PV^B_4	1.79	1.79	0.39		0.55	1.44
PV^B_5	1.85	1.83	0.61	0.55		1.48
PV^B_6	1.70	1.75	1.41	1.44	1.48	
CP^B	**1.10**	**1.11**	**0.73**	**0.77**	**0.84**	**1.06**

Similarity Index Matrix of Platform PF-B

SI_{jk}	PV^B_1	PV^B_2	PV^B_3	PV^B_4	PV^B_5	PV^B_6
PV^B_1		88%	36%	34%	32%	37%
PV^B_2	88%		36%	34%	33%	36%
PV^B_3	36%	36%		86%	78%	48%
PV^B_4	34%	34%	86%		80%	47%
PV^B_5	32%	33%	78%	80%		46%
PV^B_6	37%	36%	48%	47%	46%	
CP^B	**19%**	**19%**	**46%**	**43%**	**38%**	**22%**

Figure 5. Distance and similarity index matrix for PF-A and PF-B

For the planned new product variant (NP), the first condition (Case 1) is tested. As shown in Figure 6, this condition is not fulfilled. The next condition (Case 2), also shown in Figure 6, is however fulfilled for the Platform A (PF-A) as the Euclidean distance between the new product variant and the center point of PF-A is smaller than the maximum allowed distance. Therefore, only PF-A will be considered for the next evaluation.

Distance to Product Variants of PF-A

d_{nj}	PV^A_1	PV^A_2	PV^A_3	PV^A_4	PV^A_5	PV^A_6	CP^A	Max $\{d_{Mj}\}$: Max	d_{max}
NP	0.77	0.77	1.24	1.24	1.44	1.53	0.96	0.91	1.19

Distance to Product Variants of PF- B

d_{nj}	PV^B_1	PV^B_2	PV^B_3	PV^B_4	PV^B_5	PV^B_6	CP^B	Max $\{d_{Mj}\}$: Max	d_{max}
NP	2.79	2.84	1.98	2.16	2.21	2.08	2.17	1.11	1.36

Figure 6. Verifying Case (1) and Case (2)

In the next step, the validity of Case (2a) will be checked for PF-A. As shown in Figure 7 (left), the platform can be divided in two clusters. Although it would be also possible to divide the platform into more than two clusters, we decided against it, as the approach is supposed to reduce the complexity in managing product variants. By creating more clusters, more effort it is required to manage the clusters. After theoretically dividing the platform in two clusters (PF-AY and PF-AZ), the next step is to find the partition point that minimizes the distances between the product variants of each platform. In this paper, two iterations are presented. In the first iteration, which is shown in Figure 7 (top right), the new product variant (NP) is grouped together with PV_1 and PV_2. The result of this partition shows, that both similarity ranges of the new platforms, which is implicated by the largest Euclidean distance to the center point, are bigger than the similarity range of the original platform. Hence, the condition challenged in Case (2b) is not fulfilled. The second iteration, which is shown in Figure 7 (bottom right), yields a better result for the second platform (PF-AZ). However, similar to the first iteration, the largest Euclidean distance of the first platform (PF-AY) is greater than the largest Euclidean distance of the original platform (PF-A). This results in the decision, that instead of dividing the platform PF-A, this platform should be rather updated to include the new product variant (Decision 3).

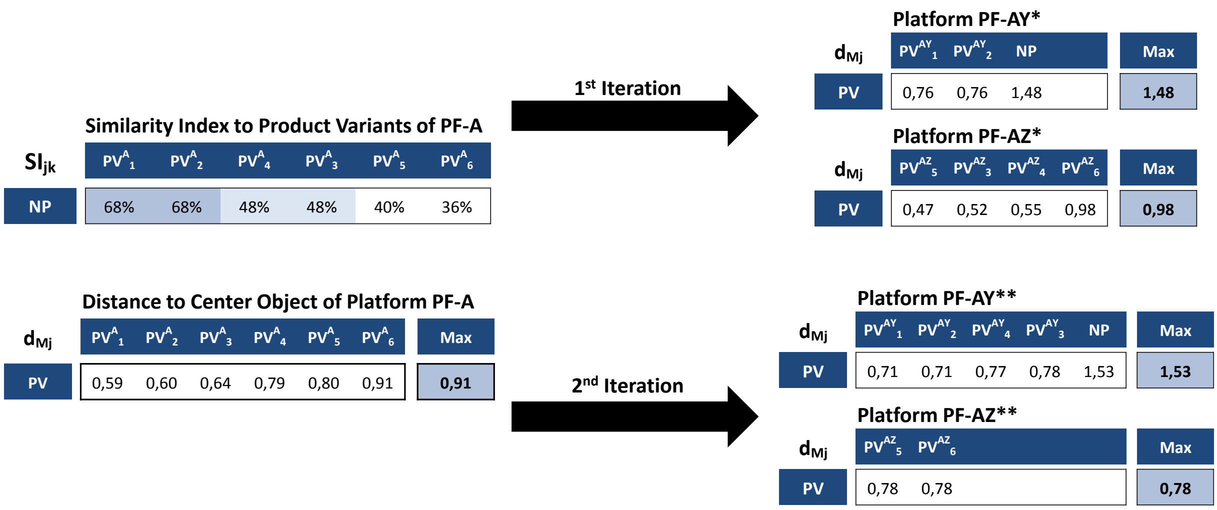

Figure 7. Verifying Case (2a) and Case (2b)

6 OPPORTUNITIES AND CHALLENGES

The introduced decision support method in this paper offers a first approach for the planning and decision making in the conceptual design phase of new product variants. Using the degree of similarity as foundation, a recommendation for the development method of a new product variant can be derived. Furthermore, this concept can not only be used for the holistic planning of a new product variant. It is also possible to use the approach presented in the decision tree for modular parts or assemblies. In that

case, the characteristic attributes are focused on the overall features of the product variant in the initial phase of the design process. As the design process advances, the main focus of the planning shifts to the module or part level and the characteristic attributes become more detailed. Because the modular platform consists of modular building blocks that are independent from each other, it is also possible, that a part of a product variant is developed using one module of a platform while other parts are developed with other modules from a different platform.
On the other side, the concept still has to face some challenges. Because it is assumed that several platforms already exist in the company and similar products should be already grouped in a platform, it is possible that the recommendation for the development method of a new product variant derived from the decision tree is not feasible at all, if the product variants are not reasonably grouped in the same platform based on their degree of similarity. Furthermore, the choice of the characteristic attributes and the weighting factors also has great implications for the decision made using the similarity index based on the characteristic attributes and the grouping of several product variants in a platform.

7 CONCLUSION AND FURTHER RESEARCH

The previously used Euclidean distance and the derived similarity index may offer a first approach to weigh up the options regarding the choice of the platform. However, the actual costs incurred due to an update or decomposition of a modular platform cannot be captured with the current state of the proposed concept. Hence, further work is required to include a cost analysis in this concept.
Another possible additional extension of the model would be to introduce constraints on the characteristic attributes of the variants and analyzing their interaction with each other, in order to investigate its impact on the decision. In the proposed approach, all characteristic attributes were calculated in the same way. However, this is not always the case in real world application due to technical restriction and compatibility factor of the modules. A detailed modeling of the attribute constraints could therefore improve the usability of the concept.

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