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CATAGORIZING VARIABLES USED FOR PRODUCT CONFIGURATION

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Abstract: *The number of combinations which can be calculated for configured products is often an enormous number. The number, even if it could be handled, still does not indicate how much customer variety or manufacturing complexity it causes.*
Based on an empiric case study, this research indicates that it is necessary to categorize the variables for mechatronic product to identify customer variety and manufacturing complexity. It is indicated that customer variety and manufacturing complexity cannot be depicted from the type of variables alone, hence more research is needed. Earlier research has indicated that designing mechatronic products for product configuration and mass customization could be done from a structure / function design view, which is discussed in this paper.

Key Words: ***Mass Customization and Personalization, Mechatronic Products, Product Configuration***

1. INTRODUCTION

The advantages of using Customization and aiming for use of Product Configuration (PC) when designing mechatronic products has been revealed in previous research [1]. Since customers have individual demands, manufacturers have to decide to what level these demands must be fulfilled. Many suppliers have learned that many product variants may increase the cost of manufacturing dramatically and non-profitably.

Mass Customization (MC) introduced by Davis [2] and followed by Pine [3][4], is often seen as a solution to this problem and, since then, MC has called for a change of paradigm in manufacturing. Several companies have recognized that MC is needed and much effort has been put into identifying, which success factors are critical for an MC implementation and how different types of companies have used it beneficially [5][6][7][8].

The best way to implement MC most appropriately varies and, for obvious reasons, there are different strategies between different companies, markets and products. Newer research underlines that MC is a strategic non-reversible development and suggests that the change process is considered as a strategic mechanism [9]. Because there is not one single generic strategy, it is important to look at the issue from different viewpoints.

The fact that products must be easily customizable in order to achieve MC has been described comprehensively in the literature and, more generally, [5]and [4] have discussed the issues related to readiness of the value chain.

One area of interest is the variety PC and MC creates. Obviously optimized variety is in the interest on the customer side and on the other side a minimized manufacturing complexity is of interest in the production [10]. In applications it would be addressed as high variety for the customer and less variety for the production. Looking specifically at mechatronic products; an optimization with less variety in the structural level and higher variety in functional level could have some interest [1]. An optimization of variety between the structural level and functional level would present more variety for the customer and presumable less manufacturing complexity in the production.

Since designing and redesigning products would aim for less manufacturing complexity in the production and higher variety for the customer, methods to identify manufacturing complexity and variety could have some degree of interest. Both could be simplified to do a measurement of the variety or the numbers of variants, a combination of the product‘s modules and variables would create. Parameters like less or higher numbers of variety could then be the goals aiming for redesign or new design.

How can it be determined if a design or re-design is less complex to produce and have higher variety for the customer? In which way can a (simple) calculation give an indication of manufacturing complexity and customer variety? To answer these questions a case study [11], has been done as an empiric survey and has included ten products, marketed and sold with the use of product configurators.

The result is – not surprisingly - that numbers of variants or the variety grows to numbers we are unable to

comprehend. The variety calculated for relatively simple products can easily reach number at 10^{12}, 10^{15} or higher. Furthermore the results show that calculation of combinations will not reveal any kind of potential manufacturing complexity a single variable can cause in the production line.

It is concluded that further survey has to be done to categorize the variables; and it is likely that the classification can be used as a foundation to form a simpler way to calculate the variety and manufacturing complexity.

2. METHODS

As stated, an empiric survey, covering ten products all sold by use of a product configurator, has been done. The result of the survey has established facts about the number of variables, what type of variables, and the number of constraints involved in the product configuration process. Based on the result a number of combination, a configured product can produce, is calculated for each of the involved products. Results of the empiric survey are used as base for the discussion and conclusion.

For the empiric survey ten products was selected with the restriction that the product configurator should be available on-line. Diversity in the list of ten was established by randomly doing a gross listing approx. 25 products found by choosing among the list of companies using product configurators found at Configurator Database [12]. The list of ten, to be used for the survey, was selected as a pre-survey done by visiting the homepage of each company from the gross list. The degree of use of product configuration was subjectively assessed and because several of the product configurators have entries to more than one product model, one model has been selected for the survey. The final list of ten was then subjectively made from this list.

The survey was performed as a registration of 1) the variables representing the product family, 2) selection of type of variables 3) constraints found. The type of variables is divided into 3 classes (A, B and C),: variables, type A, with a fixed set of possible identifiers e.g. 'red', 'blue', and 'green' or, e.g. 'round' and 'square', variables type B, with discrete integer interval of values, e.g. n = [4,,18], and variables, type C, with continuous interval of values, e.g. x = [4;18].

The results of the survey are in a table presented as a summary of ten individual tables.

Through analysis, of the data collected, it will be assessed if they can reveal the information which is necessary for optimizing variety for the customer and reduce manufacturing complexity in production.

3. RESULTS

Input data for the survey is presented in the following table (Table 1). The input data has been achieved by use of a random and subjective selection process. All input data has been retracted from the Configurator Database and used as input during the period of survey from 3rd of March to 6th of March 2010

The survey has resulted in individual tables for each of the product family involved in the survey and these tables has been summarized in one table (table 2).

Based on the result from the survey a combinatory calculation of the variety has been done (table 3).

Table 1 *Datasets for the survey.*

Company	Homepage	Product family
Konrad Krauss	kraus.atbit1.de	Dino Dual
DELL	www1.euro.dell.com	Latitude E5400
SparVinduer	sparvinduer.dk	dannebrogsvinduer
Pool Power Shop	poolpowershop.de	Oval
Mars Inc.	mymms.com	Na
Akkuline	akkukonfigurator.de	Na
FootJoy	footjoy.com/myjoys	FJ ICON Trad.
Tailor Store	tailorstore.se	Skjortor
BMW	bmw.de	X6
Hanse Yacht	hanseyachts.com	545

A number of possible combinations have been calculated and the result is under influence of the constraints involved. How much or how little influence the constraints have on the combinatory calculation cannot be resolved directly from the data collected in the survey, but a subjective assessment of the variables with constraint relationship has been used to remove non existing combinatory variants.

Table 2 *Summery of the survey.*

Company	# Variables	Type			# Constraints
		A	B	C	
Kraus	7	5	1	1	1
DELL	26	26	0	0	5
Sparvinduer	10	7	1	2	2
Pool Power	7	7	0	0	5
Mars	7	3	2	2	4
AkkuLine	11	8	2	1	2
FootJoy	16	12	4	0	9
Tailor Store	41	27	1	13	18
BMW	61	60	0	1	31
Hanse Yachts	28	28	0	0	13

Furthermore type C variables, with continuous interval, has been grouped into discrete intervals (inspired by Shaw [13]) to avoid the result of combinatory calculation to be infinitive.

Table 3 *Calculation of combinations based on the variables*

Company	Combinations
Kraus	$2{,}1\ 10^{7}$
DELL	$4{,}0\ 10^{12}$
Sparvinduer	$3{,}1\ 10^{13}$
Pool Power	$1{,}1\ 10^{4}$
Mars	$1{,}1\ 10^{22}$
AkkuLine	$1{,}8\ 10^{8}$
FootJoy	$1{,}4\ 10^{51}$
Tailor Store	$3{,}7\ 10^{57}$
BMW	$1{,}3\ 10^{28}$
Hanse Yachts	$3{,}4\ 10^{17}$

4. ANALYSIS

Based on the results presented in Table 2, it is not possible to establish exact knowledge about the variety or manufacturing complexity. None of the data collected

individually or combined reveals any specific expression of the variety or manufacturing complexity.

By analyzing the number of variables involved in a product configuration (Table 2) it is relatively evident that 3 of the ten candidates (Krauss, Pool and Mars) have the lowest number of variables and as an opposite a different candidate (BMW) has the highest number of variables involved. But none of these numbers can be used as an assessment of how optimized the offered variety to the customer is. Looking at the variety they can be configured to, shown in Table 3, they have great differences, but it can (only) be established that we have high numbers of variety no matter which of the products we choose among.

To review the manufacturing complexity the results gives no exact information, and going closer to each variable involved, neither of the data collected gives any further information about the manufacturing complexity. Reviewing individual variables by using the classification set prior to the survey, neither can reveal the manufacturing complexity involved.

5. DISCUSSIONS

Based on the result and analysis it can be argued that using a classification of variables as in the empiric survey presented seems not to clarify how much customer variety or how much manufacturing complexity these variables cause.

Analyzing the types A versus B/C variables, it seems that doing the combinatory calculation for possible variants the results have a distortion coming of the nature of B/C types. Type B/C variables will not necessary cause more manufacturing complexity if the interval is a few variants or many, e.g. 5 variants compared to 100.000.000.000 variants, by using parametric design would not necessarily cause a higher degree of manufacturing complexity. On the other hand an outcome change from 2 variants to 4 variants for type A variables will probably cause a double manufacturing complexity.

Earlier research has indicated that it would ease the design process of mechatronic products for PC and MC using a framework of structure and functions [1]. Reviewing the literature in the design domain [14] [15] [16] [17], the use of function – behavior – structure framework has revealed a possible path to categorize the variables. Relation between the function / structure and customer variety and manufacturing complexity is discussed in the following paragraphs.

It is argued that manufacturing complexity is related to the structure of the device [17][14]. Using such a view will identify relationships of components because the representation is based on the physical organization of components, which could represent the manufacturing complexity as well. The structure framework of physical components could be expressed as a set of variables. For example a plain table consists of 6 components four legs, a frame, and a tabletop. This could be set as 3 variables all a part of the manufacturing complexity, take the variable *legs* and make them variable in two materials as wood and metal. Make *wood* available in oak and birch, and metal available in chrome and 2 colors. Wood and metal would be twice manufacturing complexity. Manufacturing of oak or birch will not apply further complexity, but legs in chrome or in 2 colors would apply further manufacturing complexity.

It could be argued that the use of functional structuring [17][14] could reveal the customer variety, because in a functional structuring representation a devices set of functions could be expressed as a set of variables. In functional structuring it is possible to decompose the device's function into components' functions. For example the table is now with adjustable height of legs. The function *height of table* could be design as several fixed lengths of sets of legs, or manually adjustable legs, or motorized adjustable legs. Each type is representing the same function *height of table*, which is comparable with the customer variety.

6 CONCLUSIONS

Clarifying a way to express the customer variety and the manufacturing complexity of customizing products was the initial scientific goal. An empiric survey was the foundation for datasets to be analyzed and discussed in this paper. The survey based on ten product models was used as reference to establish the knowledge about how to express variety and manufacturing complexity.

It has been revealed that it is not possible from those data collected in this survey, that customer variety can be expressed using knowledge about the variables variants and the type of variable. It is possible to calculate a number of possible variants as a simple combinatory calculation, but it has also been clarified that this number in a practical application would be so large that it cannot be processed for any kind of action to take. It is concluded, as well, that the manufacturing complexity cannot be revealed from a list of variables without further information about the variable.

For further research is has been indicated that using a function – behavior – structure framework could reveal how to categorize variables to express manufacturing complexity and customer variety.

7. REFERENCES

[1] K Nielsen, K Joergensen A., T Petersen D., *Mechatronics and Mass Customization*, 2010 (2009).

[2] SM Davis. *From "future perfect": Mass customizing*, Strategy & Leadership. 17 (1989).

[3] BJ Pine II, B Victor, AC Boynton. *Making Mass Customization Work*, Harv.Bus.Rev. 71 (1993) 108-118.

[4] BJ Pine, *Mass customization: the new frontier in business competition*, Harvard Business School Press, Boston, Mass., 1993.

[5] B Berman. *Should your firm adopt a mass customization strategy?* Bus.Horiz. 45 (2002) 51-60.

[6] JH Gilmore, BJ Pine, *Markets of one: creating customer-unique value through mass customization*, Harvard Business School, Boston, Mass., 2000.

[7] D Sabin, R Weigel. *Product configuration frameworks-a survey*, Intelligent Systems and their Applications, IEEE. 13 (1998) 42-49.

[8] D Silveira Giovani, D Borenstein, FS Fogliatto. *Mass customization: Literature review and research directions*, Int J Prod Econ. 72 (2001) 1-13.
[9] F Salvador, P de Holan Martin, F Piller. *Cracking the Code of Mass Customization*, MIT Sloan Management Review. 50 (2009) 71-78.
[10] J Lampel, H Mintzberg. *Customizing Customization*, Sloan Manage.Rev. 38 (1996) 21-30.
[11] RK Yin, *Case Study Research: Design and Methods*, Third Edition, Applied Social Research Methods Series, Vol 5 3rd ed., Sage Publications, Inc 2002.
[12] Piller F., et al., *Explore the world of configurators! — Configurator-Database,* http://www.configurator-database.com / march, 2010.
[13] DG Shaw, MD Huffman, MG Haviland. *Grouping Continuous Data in Discrete Intervals: Information Loss and Recovery*, Journal of Educational Measurement. 24 (1987) 167-173.
[14] L Qian, JS Gero. *Function–behavior–structure paths and their role in analogy-based design*, AI EDAM. 10 (2009) 289-312.
[15] Y Umeda, H Takeda, T Tomiyama, H Yoshikawa. *Function, behaviour, and structure,* Applications of artificial intelligence in engineering V. 1 (1990) 177-193.
[16] B Chandrasekaran, AK Goel, Y Iwasaki. *Functional Representation as Design Rationale*, Computer. 26 (1993) 56.
[17] AM Keuneke. *Device representation-the significance of functional knowledge*, IEEE EXPERT INTELLIGENT SYSTEMS and THEIR APPLICATIONS. (1991) 22-25.

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