Key-words: product configuration, knowledge-based systems

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PRODUCT CONFIGURATION USE CHOSEN ARTIFICIAL INTELLIGENT METHOD

Abstract:

Product adjustment to customer expectation, which means product customization, decides about its commercial success. Developing methods helpful in the early phase of product design is needed to product customization. The aim of this paper is to present application of knowledge-based systems (KBS) in product customization.

1. INTRODUCTION

Product adaptation to the new application is a way of product development which assures product quality in regard to manufacturability and economic aspect.

Product planning needs information related to customer expectation and product characteristic. The method helpful in the product planning is Quality Function Deployment QFD developed by prof. Akao. The model of product planning was presented on the Fig 1.

Many authors develop computer supported techniques in product development [1, 11, 15, 18 ,19, 24, 28]. But still exits the gap in the computer technique supported decisions in early phase of product development. Fulfil customer needs is the most important task of product development in context of product customization. The link between customer expectation and product characteristic is the crucial point in product planning.

Customer needs (Fig.2) could be divided into two categories: revealed - related to product trade features which can be satisfy in proportion like low price, fast delivery, long warranty period and expected - related to products technical characteristic which decided about products utility and their functions.

The design problem includes, among others the problem of product decomposition [14].

Product configuration issue needs information related to product's functions and components that implement the function. Product physical elements named components assembled together are accomplishing product functions.

Product decomposition gives information about physical elements that must be selected or designed to perform the product function. Product functional decomposition should represent

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the intended behaviour of products and their parts. [30] Product functions are divided into sub functions. The functional breakdown is continued until functions are mapped into components.

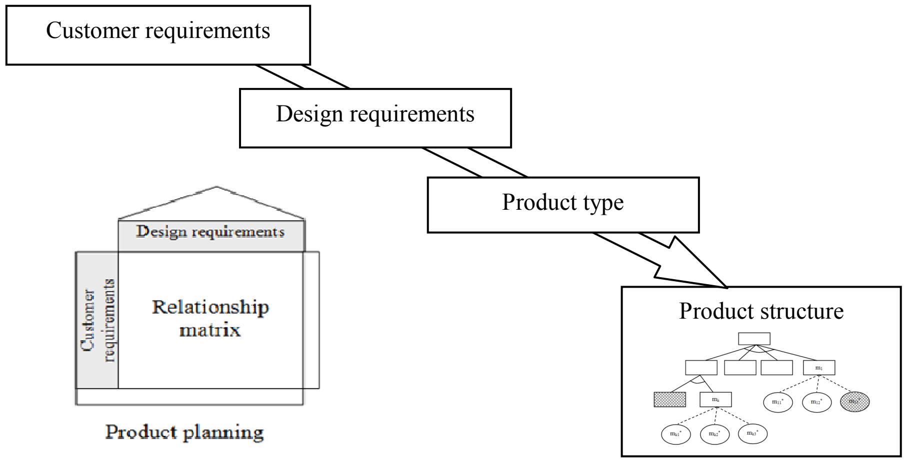

Fig.1. The model of product planning

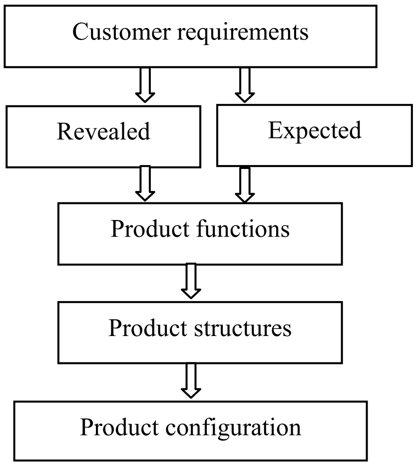

Fig.2. The idea of product configuration

2. PRODUCT CONFIGURATION

2.1. Product decomposition

One of the most important problems in product configuration issue is product decomposition which provides the combination of components which gives product suitable for particular client. Product decomposition and functional requirements will help to answer the following question: which physical element(s) is responsible for the fulfillment of a specific functional requirement? [29]. In literature we can find different approaches to product decomposition. According to [10] to describe the product assortment and the variants in the product portfolio Product Variant Master (PVM) can be used. This approach includes generic kind of structure and generic part structure which consists of modules or units divided into parts described by attributes.

The functional approach to product decomposition was presented by [12] who used the hierarchy of functional requirements as a structural set of classification parameters. To describe both families and their variants in a single formalism, a combined decomposition/classification tree is adopted to represent functional classification from an abstract level to individual instances [12].

In product platform customization, the concept of Generic Bill-of-Material (GBOM) is adopted as a generic data structure [20]. A GBOM is defined as an AND/OR tree structure composed of five types of modules: AND module, OR module, SCALABLE module, INSTANCE module and EMPTY module.

Huang and Kusiak [13, 8] offers modular product configurations, which consists of different types of modules includes: basic modules: auxiliary module, adaptative modules and non-module: designed individually for specific product functions.

Another approach [21] developed a customer-oriented product design procedure based on user's characteristics. This procedure includes design input and output parameters, and their relationships. The designer first identifies design input and output parameters and values for the targeted product. Based on a specific set of user requirements, the approach will identify possible design output parameter values that can meet these requirements. A random assignment procedure is then employed to generate feasible design alternatives [21].

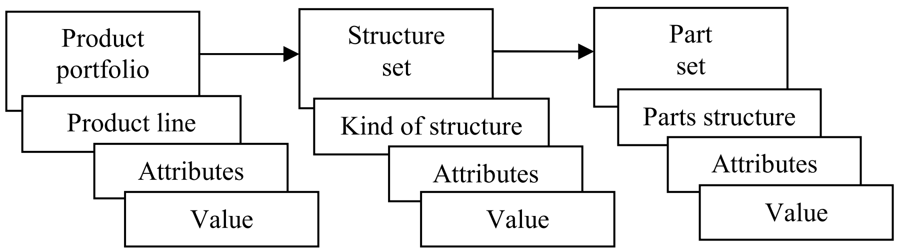

Fig.3. The idea of product decomposition

In the proposed approach to product configuration, the idea of product decomposition applied in Product Variant Master (PVM) is used (Fig.3). The proposed idea of product decomposition includes three levels of classification. The first classification level includes products portfolio (product line) and their attributes and values, each product line is characterized by a set of similar product structures (e.g. helical reducers) which use particular parts set.

2.2. Product configuration algorithms

Product configuration research mainly focused on configuration algorithms, which based on the following approaches [22]: rule-based reasoning which uses rules as mechanism to represent knowledge, logic-based approach which used semantic and logical operations, resource-based approach in which technical requirement, components as well as environmental connections are represented as abstract resources, constraint-based approach in which each component of the product is defined by properties and parts, and case based reasoning using sets of existing configurations for reasoning.

Researchers widely used product platform as a tool for product configuration, which is defined as a set of subsystems and interfaces developed to form a common structure from which a stream of derivative products can be efficiently developed and produced [20].

In product platform, customer requirements are given as inputs and the solution is a product variant or a range of several variants that satisfy customer requirements and constraints while optimizing performance and/or economic objectives. [20]

In literature we can find different product platform PP customization strategies such as: scalable, configurable, adaptive. The scalable PP approach means a family product variants composed of particular components, the differences between which lie in parameter values. The optimization problem in this case is a parametric design optimization problem under the fixed product platform architecture. [20]

In the configurable PP, product variants are created using pre-designed modules. The optimization problem is a structural configuration problem in which modules are selected from given modular platform.

The adaptive PP is a mix of approaches described above, where modules can be swapped but some of them can be scaled to satisfy customer needs. The optimization problem includes structural and parametric optimization.

Finding the optimal product profile from a product family for particular customer is an optimization problem which includes problem of modeling process of translating customer requirements to engineering characteristic.

2.3. QFD in product design

QFD was originally used as a tool for collecting and analyzing data related to customer needs and to develop higher quality products. Primary functions of QFD include product development, quality management, and customer needs analysis. Now, QFD's functions had been expanded to wider fields such as design, planning, decision-making, engineering, management, teamwork, timing, and costing. [3].

QFD has its origin in Japan. Prof. Joji Akao and co-workers improved the design process, which was called QFD. The first QFD application was in the Kobe Dockyard of Mitsubishi Heavy Industries. From late 1970s, QFD was integrated with other improvement tools and was successfully applied in many Japanese, American, Australian, German, Italian, Danish, Brazilian and others plants [3]. QFD has been introduced into the whole Toyota group with impressive results and also has been successfully used in many other Japanese industries, such as agricultural systems, construction equipment, consumer electronics, home appliances, integrated circuits, software systems, steel, synthetic rubber, and textile [3].

Early adopters of QFD in the USA included: 3M Company, AT&T, Baxter Healthcare, Budd, Chrysler, DEC, Ford Motor, General Motors, Goodyear, Hewlett-Packard, IBM, ITT, Kodak Eastman, Motorola, NASA, NCR, Polaroid, Procter and Gamble, and Xerox. QFD as a improvement tool continues to grow in popularity. [3]

In spite of QFD popularity, authors in many publications point out some difficulties in its applications.

According to literature review including 157 articles in 5 years period, made by [2] “it is necessary to investigate … applications would make QFD still more complex... Further work encompasses research in this direction, i.e. to reduce difficulties in the use of QFD.”

The problem discussed in the article is how to choose the product configuration to satisfy particular customer needs. To solve this problem in the proposed approach, QFD matrix of product planning and part development is used (Fig.4).

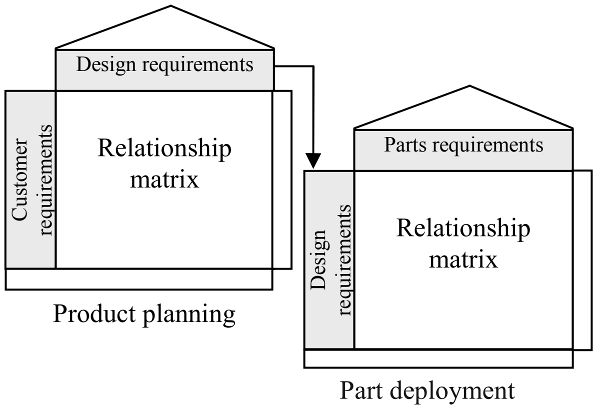

Fig.4. QFD matrix

3. KNOWLEDGE BASED SYSTEM IN NEW PRODUCT DEVELOPMENT

Knowledge Based System (KBS) in area of product and process design support designers in making decisions regarding to design improvements and selecting the near optimal design, especially by means of providing them with a timely feedback in regard to manufacturability and economic aspect of each product and process design. [27].

Customer requirements analysis could be supported by QFD tool. Basic QFD knowledge based systems can be develop in a modular format and create integrated decision-making expert system which [27]:

- help translate customer requirements into product specifications,
- assist in quality product design based on product specification,
- assists in optimal process design based on product design and specifications,
- translate product and process design into quality manufacturing,
- define final test procedure and criteria to ensure product quality,
- prepare cost projection based on customer requirements and specifications
- prepare cost estimate based on actual product and process design,
- prepare final product cost based on actual manufacturing costs.

KBS module developed in the paper is focused on translating customer needs into product characteristic. Customer needs are understand as expected and revealed. So data analysis focused on technical product characteristic and trade data.

An example of if-then rules was presented on the table 1.

Tab.1. An example of if-then rule

<table>
<tr><td colspan="3" rowspan="4">Product type

Product characteristic</td><td colspan="6">Then (or)</td></tr>
<tr><td colspan="3">Product type 1</td><td colspan="2">Product type 2</td><td>…..</td></tr>
<tr><td colspan="6">Product alternative</td></tr>
<tr><td>l_1</td><td>l_2</td><td>..</td><td>l_1</td><td>l_2</td><td></td></tr>
<tr><td rowspan="9">If
(and)</td><td rowspan="3">Attribute 1</td><td>Range of value 1</td><td colspan="3">1</td><td colspan="2"></td><td></td></tr>
<tr><td>Range of value 2</td><td colspan="3"></td><td colspan="2">1</td><td></td></tr>
<tr><td>….</td><td colspan="3"></td><td colspan="2"></td><td></td></tr>
<tr><td rowspan="3">Attribute 2</td><td>Range of value 1</td><td colspan="3">1</td><td colspan="2"></td><td></td></tr>
<tr><td>Range of value 2</td><td colspan="3"></td><td colspan="2">1</td><td></td></tr>
<tr><td>…..</td><td colspan="3"></td><td colspan="2"></td><td></td></tr>
<tr><td rowspan="3">……..</td><td>Range of value 1</td><td colspan="3">1</td><td colspan="2"></td><td></td></tr>
<tr><td>Range of value 2</td><td colspan="3"></td><td colspan="2">1</td><td></td></tr>
<tr><td>…..</td><td colspan="3"></td><td colspan="2"></td><td></td></tr>
</table>

Tab. 2. Components alternative

Components	Alternative	Labour consumption	Costs
m_1	m_{11}^* m_{12}^* m_{13}^*	$T_{11}^*(n)$ $T_{12}^*(n)$ $T_{13}^*(n)$	K_{m11}^* K_{m12}^* K_{m13}^*
m_2	m_{21}^* m_{22}^*	$T_{21}^*(n)$ $T_{22}^*(n)$	K_{m21}^* K_{m22}^*
….			
m_k	m_{k1}^* m_{k2}^* m_{k3}^*	$T_{k1}^*(n)$ $T_{k2}^*(n)$ $T_{k3}^*(n)$	K_{mk1}^* K_{mk2}^* K_{mk3}^*

If-then rules point product type which preliminary fulfil the mine expected customer needs. But to fulfil particular customer needs the product structure analysis is needed.

The proposed approach based on the model developed by [12], in which a set of components was denoted M and consists of k components $M = \{m_1, m_2, \ldots, m_k\}$, $\forall k \in \{1, \ldots, K\}$. Each component m_k is one of the elements of the feasible configuration design alternatives set $M_k^* = \{m_{k1}^*, m_{k2}^*, \ldots, m_{kl}^*\}$, $\exists m_{kl}^* \in M_k^*$, $l \in \{1, \ldots, L_k\}$, $k \in \{1, \ldots, K\}$.

Analysis of trade data mainly focused on costs estimation [16]. The table 2 includes data related to costs estimation of alternative solutions.

Labour consumption is calculating according to formula (1):

$$T^z(n) = t_r^z + \sum_{i=1}^{mk} \sum_{x=1}^{X} \left(t_{pz_{ix}}^z + n \cdot t_{j_{ix}}^z \right) \quad (1)$$

where: t_r^z – labour consumption of engineering drawing preparing of *z-th* product,
$t_{pz_{ix}}^z$ – set-up time of *x-th* operation for *i-th* component of *z-th* product,
$t_{j_{ix}}^z$ – unitary time of *x-th* operation for *i-th* component of *z-th* product.

Cost is calculating according to formula (2).

$$K = k_r \cdot t + k_m \quad (2)$$

where: k_r – processing costs per hour,
t – labour consumption,
k_m – material costs,
K –manufacturing costs.

4. CONCLUSION

In global competition product customization is one of the most important enterprise goals. To satisfy customer needs is necessary to offer reliable product suitable for particular client. Product customization is necessary to increase enterprise competitiveness. Quality and costs requirements cause the need of product configuration with well known product core and redesign of only chosen product components.

Among methods which are useful in transformation of customer needs to engineering characteristic, QFD—quality function deployment is one of the most important. QFD is dedicated to translating client requirements into activities to develop products and services. According to literature review made by Carnevalli et al. [2] researchers points some difficulties in QFD application which discouraged its use. For this reason, is important to carry out studies to QFD development which facilitate its application in the future.

Proposed approach joint QFD matrix and artificial intelligence method. AI methods include knowledge –based system which is still relatively new. This paper presents KBS applications in the context of product customization in economic and timely manner.

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