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MFF CONTRIBUTION IN PRODUCT DEVELOPMENT PROCESS

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Abstract: *The paper presents MFF (Matrix of Function and Functionality) model implemented in computer application to help development of new products or their parts. MFF is developed as a tool that helps designers in earl phases of product development (conceptual phase), when all details of product are not known. Matrix, by means of mathematical rules, relates in relation functions and functionalities. Functionalities are known technical systems that are stored in application database and present design knowledge. With this knowledge, by means of MFF, is possible to generate new products. The paper also presents products developed by means of MFF model.*
Key Words: ***MFF (Matrix of Function and Functionality), Product Development, Conceptual Design, Function, Functionality***

1. INTRODUCTION

In order to increase the probability of success of a new venture, the design process must be planned carefully and executed systematically. In particular, an engineering design method must integrate the many different aspects of designing in such a way that the whole process becomes logical and comprehensive [1]. In order to solve a technical problem we need a system with a clear and easily reproduced relationship, between inputs and outputs (Fig. 1). To that end it is always useful to make a block diagram in which the process and sub-systems inside a given block (black box) are at first ignored (Fig. 1).

With the purpose of solving technical problems different methods were developed [2]. The most easily generalized among these methods is the morphological technique by Zwicky [3, 4], which concerns itself with the intrinsic structural characteristics of the formation and content of the thought process. In [5, 6, 7] matrix models were presented, which enable the generation of a functional structure of the product, described in matrices. The background of most matrix models is represented by morphological box [3], which forms the basis for further development.

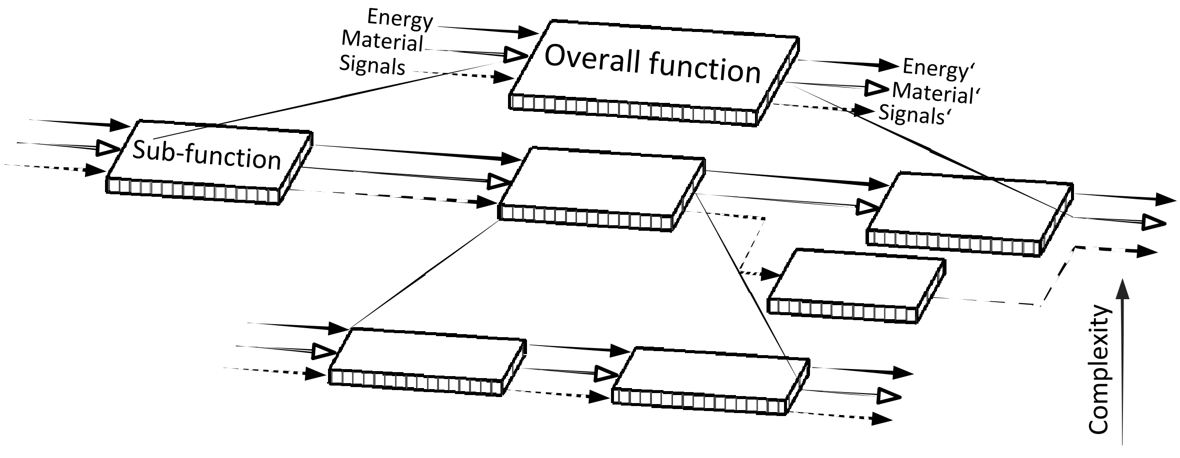

Fig. 1. Establishing a function structure by breaking down an overall function into sub-functions

In order to generate product's shape structures, new functional structures are essential. To generate them, important philosophies of engineering of technical functions must be considered [8, 9]. In [10], the authors approach describing the functions by defining the terminology that is related to the names of the functions, while others describe the functions of technical systems by means of physical laws [11]. With a view to unique identification, rules were defined [5], by means of which the functions, functionalities and products are described.

Market requirements are the basis for defining basic functional requirements, which in turn represent the initial information on a new potential product [12, 13]. At the beginning of the design process, functional requirements are usually unarranged, incomplete and sporadically presented, which makes them necessary to be arranged, complemented and expanded. By means of structural enlargement of functions, product structure can be presented as a functional structure, which is at the same time the basis for defining the shape (physical structure) of the product [14].

Research and development activities within the product-development process have their own characteristic and distinctive features, dominated by unpredictability, creativity, mentality and abstraction. Due to these features it is difficult to thoroughly describe, develop and implement the design process in the initial phases of computer-tools development [14, 15].

2. THE MATRIX OF FUNCTION AND FUNCTIONALITY - MFF

The matrix of function and functionality – MFF – is a methodology that can serve an individual, i.e. a designer, to find and analyse various solutions of functional requirements in a repeatable way. In the later stages, it allows easier generation of product's new and variant functional and physical structure. On the basis of a mathematical model [16], function description rules [17], and morphological matrices guidelines, MFF integrates functional requirements and functionalities [17] that in part or in whole fulfil them. These links represent possible solutions that MFF verifies and searches. If a link between a functional requirement and functionality is possible, it yields a result, otherwise, it is not displayed. We can to say that the MFF represents a tabular representation of bindings between function requests and functionalities (Fig. 2) [18].

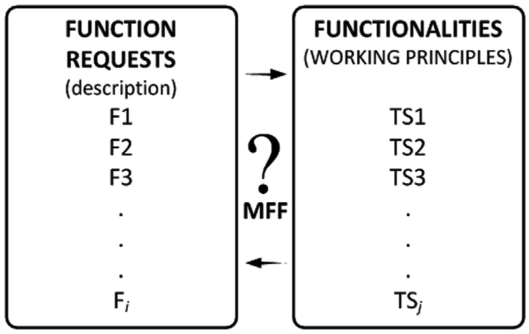

Fig. 2. Bindings between function requests and functionalities [18]

Functional requests are derived from market requirements and represent the most important attributes of the requested system – functions, while functionalities are represented by technical systems [9] or shape models that in part or in whole fulfill the required functions.

Looking at figure 3, representing a detailed MFF model, we can see that functions or functional requirements are generally marked with F*i* and are placed in the first column, while individual technical systems (functionalities) are marked with TS*j* and can be found in subsequent columns. The links between the functions and the functionalities that solve them are created by means of these-called sub-matrices. These sub-matrices are colored and highlighted in grey (Fig. 3).

FUNCTION	FUNCTIONALITY / SOLUTION			
	TS1→	←TS2→	←TS3→	←TS*j*
Functional requirement - F1 [Suggested solution] ↓	M **88** ↓		M **30** ↓	
	↑ S **49**		↑ A **40**	
Functional requirement – F2 [Suggested solution] ↑↓		S **85** ↓		M **100** ↓
		↑ S **45** ↓		↑ A **100** ↓
		↑ B **23** ↓		↑ B **56** ↓
		↑ B **15**		↑ B **33**
Functional requirement – F3 ↑↓				
Functional requirement – F4 [Suggested solution] ↑↓	M **100**	M **88** ↓		M **88** ↓
		↑ S **49**		↑ S **49**
Functional requirement - F*i* [Suggested solution] ↑	M **80**			

Fig. 3. MFF with sub-matrices [16]

MFF tends to find new design solutions for specified functional requirements, where an individual's intuition and experiences are not required. MFF uses the basics of technical functions [19], rules for describing and arranging functions into main, supplementary, auxiliary and binding functions [5] and characteristics of describing with parameters and winning parameters.

2.1. Matrix of Function and Functionality application model

MFF is a tool which is implemented into the Web application. This application is a computer tool, developed for a wide range of engineers to help development of new products or their parts. The matrix of product function and its requirements was developed as a prototype to the MFF [6, 20]. The basic idea for making application was to create a knowledge base in a specific area that contained at one place the knowledge of engineers acquired during their working life, or during product development. The knowledge base is designed as an extensible base which would be expanding by every new designed product and in that way become better and more useful. In addition to engineers beginners, this knowledge base is also very useful for experienced engineers, because it allows them to have available at one place their previous products solutions, but also the products solutions of other experienced engineers. In this way an engineer can easily and quickly resolve problems encountered during the new product development and its design.

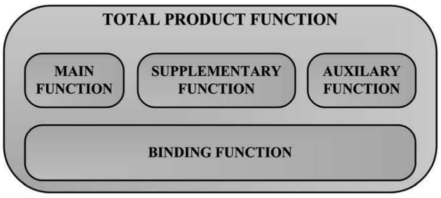

Fig. 4. Overall function of a technical system [5]

The knowledge base is formed automatically by inputting the individual characteristics of the product, which is determined by the main, supplementary, auxiliary and binding functions [5] (Fig. 4). Each product comprises records of at least one main, one or more auxiliary and supplementary functions, and at least two or more binding ones. Functions have also been described with the physical values of parameters [16, 17].

The knowledge base can be reviewed and the entered functionality is built on the principle of a self-learning system. The system has a built-in decision tree and recognition of each function so that the percentages to calculate the satisfaction of each function are calculated. After the calculation of the matrix, the user can make modifications so as to reach the final solution to the concrete problem.

3. MFF IMPLEMENTATION ON PRODUCTS

Although the design of a product must often be done in a multidimensional world, engineers are often taught concurrent techniques for the one-dimensional world. They do not know how to think in several dimensions because they have not been given the tools and techniques that can deal with that problem of a complex world.

The gap between research and practice is of concern today. Effective methods need to be developed for transferring research results to industry, therefore MFF model was developed and verified with real application and products. The MFF model is currently presented and implemented on more than twenty completely different, solved and described products from diverse design areas. For the purposes of this work, implementation will be shown on a developed product named *Active Lounge Chair 1 – ALC I* (Fig. 5).

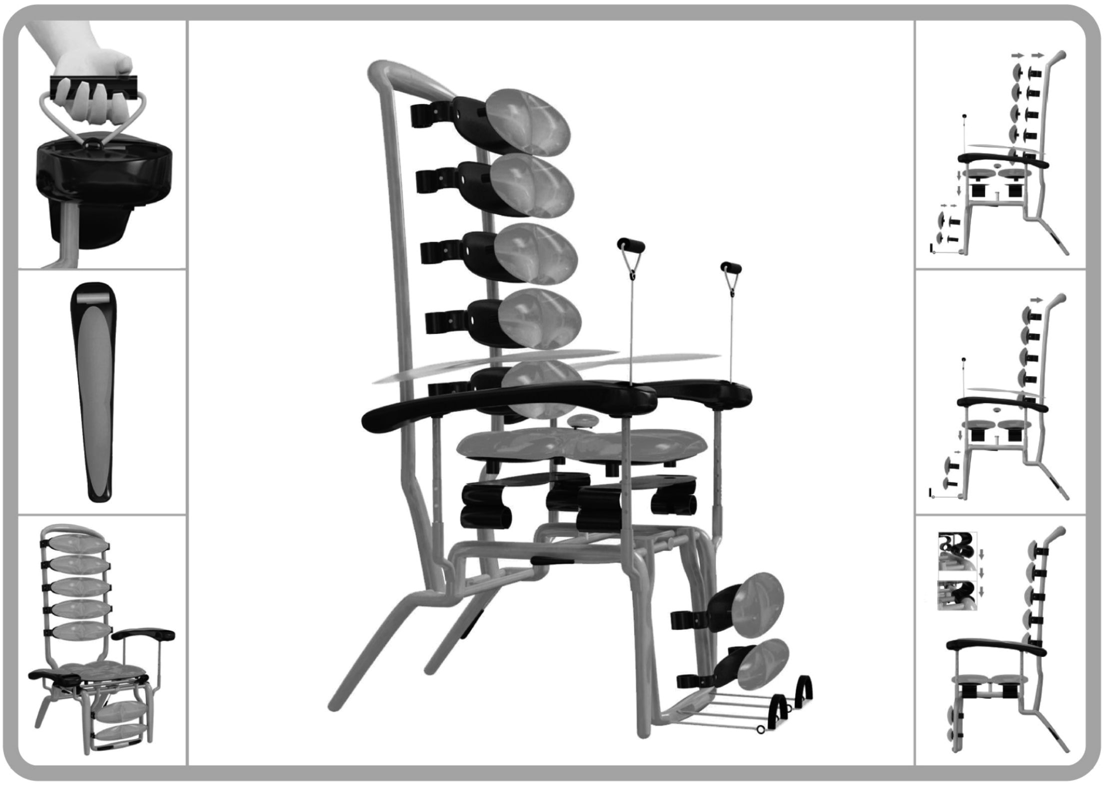

Fig. 5. Active Lounge Chair 1 – ALC 1 [21]

The idea of *ALC I* is to represents a product whose basic functions are *sitting*, *resting* and *exercising*. It is aimed at a wide range of users of all ages, where also elderly people are encouraged to exercise and consequently achieve greater vitality in old age. Research and development of *ALC I* has strived to achieve that the product shape is esthetically correct, emanates comfort, is functional and anatomical harmonious, is easy to use, is suitable from the ergonomic point of view, is practical and finally adaptable to anyone. The key components of the *ALC I* are: *the sitting part*, *the leg/foot rest, the arm/hand rest*, *the upper body rest*, and *the hand and leg exercise mechanism*, as shown in Fig. 5, where each one of the components allows and fulfills a precisely defined function.

The MFF in figure 6 represents the real MFF design view of *ALC I* design. The matrix involves several possible solutions, cross-corresponding to several functions. The main possible functionalities are *Stool*, *Fixed Armchair*, *Variable Armchair, Active Lounge Chair 1*, etc. among which it is possible to manipulate the desired functions or functional requirements: *sitting* and *resting*, *hand rest*, *possibility of vertical arm movement*, *possibility of vertical arm movement independently of lower chair part, possibility of exercise, bending, height adjustment etc*.

Generate | Update | Refresh | Truncate | Close

MATRIX FOR [LEVEL 1]: ACTIVE LOUNGE CHAIR 1 | SITTING AND RESTING

Function/ality		Stool	Fixed armchair	3D gel	Variable armchair	Active Lounge Chair 1	Back	Exercise mechanisem	Rotating pedestal
sitting and resting [12 solutions | Suggested: holding force]	▼	M 100	M 100 ↓	A 100	M 83 ↓	M 83 ↓	M 100	A 33 ↓	S 33
			↑ S 33		↑ S 33	↑ S 33		↑ M 33	
hand rest [9 solutions | Suggested: hand rest]	▲▼	M 50	S 100 ↓	A 50	S 100 ↓	S 100 ↓	M 50		
			↑ M 50		↑ M 50	↑ M 50			
possibility of vertical arm movement [11 solutions | Suggested: possibility of vertica...]	▲▼		A 100	M 20	A 100 ↓	A 100 ↓	S 20	M 60	B 20 ↓
					↑ A 60	↑ A 100 ↓			↑ M 20
						↑ S 40			
possibility of vertical arm movement independently of lower chair part [11 solutions | Suggested: possibility of vertica...]	▲▼		A 60	M 10	A 100 ↓	A 100 ↓	S 10	M 35	B 10 ↓
					↑ A 30	↑ A 60 ↓			↑ M 10
						↑ S 30			
bending [2 solutions | Suggested: alleviation possibilit...]	▲▼			M 100			S 100		
possibility of exercising [9 solutions | Suggested: possibility of exercis...]	▲▼		A 67	M 33	A 67	S 100 ↓	S 67	M 67 ↓	
						↑ A 67 ↓		↑ S 33	
						↑ A 67			
incline [1 solution | Suggested: bending]	▲▼						S 100		
height adjusment [1 solution | Suggested: height adjustment]	▲▼						A 50		
space movement [8 solutions | Suggested: space movement]	▲▼		A 50		A 50 ↓	A 50 ↓		M 50	M 100 ↓
					↑ A 50	↑ A 50			↑ B 50

Fig. 6. MFF modularity implementation view on the example of ALC 1 [21]

Fig. 6 reveals that the *Fixed armchair* variant completely replaces the *Stool variant*, as it solves the *Stool's* main function (*sitting* and *resting*), as well as another function: *hand rest and the possibility of vertical movement*, which is by default not fulfilled by the *Stool*. The function solution within the technical system is shown as a percentage value in cells, i.e., cross-intersections in the matrix. The displayed value can be highlighted in various colors, depending on the quality of the sought-after data that can be found within different function types. The probability of a suitable solution hierarchically follows in colors from the most probable green to brown and the least probable grey. Compared to the *Variable armchair variant*, the *ALC I variant* solves some other, additional functions that the former variant does not solve by default. It can be argued that the *ALC I variant*, compared to all three other variants, is more sophisticated and fulfills more functions.

The second product is Tricycle, where is on figure 7 presented concept of „*Seat positioning assembly*". The seat positioning assembly (Fig. 7) is one of the assemblies which most importantly define tricycle ergonomics, esthetics and usability of the whole product. Its main function is defined as "*Regulating settings of seating and driving positions*". The first concept (Fig. 8) we designed using the MFF was defined on the basis of two most general functional requirements: "*Acceptance of driver's mass*" and "*Vibration reduction*".

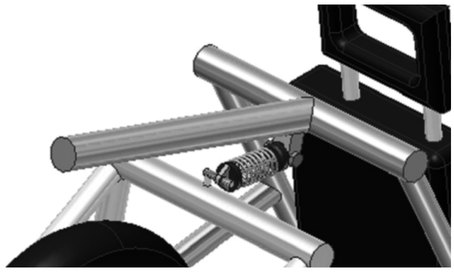

Fig. 7. First MFF concept of „Seat positioning assembly"

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MATRIX FOR [LAVEL 2]: SEAT POSITIONING ASSEMBLY | REGULATING SETTINGS OF SEATING AND DRIVING POSITIONS

Function/ality		Seat	Spring
Acceptance of driver's mass [2 solutions | Suggested: Acceptance of mass]	▼	M 75	M 25
Vibration reduction [1 solution | Suggested: Vibration reduction]	▲		M 100

Fig. 8. MFF of the first concept with the corresponding F*s and* TS*s*

Fig. 9 illustrates the design (physical) structure of the suction unit [7]. The structure is generated from the previously designed matrix structure, generated by MFF model. With the MFF model and developed Web application is possible to generate hierarchy tree of product with the correlation between the MFF matrices that constitute matrix structure of product.

Fig. 9. Suction unit design structure [7]

4. CONCLUSION

The paper presents MFF model implemented in computer application. The MFF concept consists of three parts: functional requirements part, functionality part and searching for solutions and evaluation (links). Functional requirements part defines functional requirements or desired market requirements, representing the first possible information on a future product. It is of utmost importance for the future development. The functionality part defines functionalities, i.e. individual possible solutions, working principles. As a rule, they are presented as technical systems. Each functionality is an individual unity, outwardly presented with a title while inwardly it contains specifically defined functions and parameters. A source of possible information. Searching for solutions and evaluation - searching for and evaluation of solutions for functional requirements. The solving framework is provided by a clear and presentable matrix – MFF, size $n \times m$. Within the matrix, possible answers are searched on the basis of direct relationship between the function and functionality.

The article presents a review of the current implementation of the MFF model on specific products. For this application we can see the importance and significance of the developed model in order of development new products and/or modification of existing products.

The mission of the developed model is to contribute to, and find within, the initial design processes the appropriate fundamentals for better and faster design development. The MFF upgrades and updates the deficiencies of the morphological matrix through the application of mathematically- not intuitionally based model for creating links between the function and functionality.

Future work would include development a knowledge base in a specific area that contains at one place the knowledge of engineers acquired during their working life, or during product development. The knowledge base will be design as an extensible base which would be expanding by every new designed product and in that way become better and more useful.

Based on the development of MFF system, it can be used for system analysis or prediction of a new family of products. This presents the idea that with this system of the MFF matrix we can also involve the products from the market which already presented and have the standard quality for some function. Thus, each user can build his base of standard semi-finished products, which is an essential advantage of our affordable system analysis.

Future work would also include upgrading of the application so when you add functionality with the same name, each functionality gets a serial number to distinguish each other. Also planned is the addition of recommendations most acceptable solutions for the functional requirements of a given criterion (a solution that would be chosen by some of the engineers / users of application, a solution that would be the result of the work of all previous user applications, a solution that represents the best solution to the calculated percentages, etc.). This system would be a system of artificial intelligence that with its recommendations could facilitate the user to select the final solution set of functional requirements and the final decision would have to be based only on the calculated percentages.

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