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Matlab application for the analysis of existing systems with the purpose of developing new product

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Abstract. The main design objective is to understand a technical system and to develop useful methods for developing a product. An approach for developing a new product can be a modular design that divides a product into smaller subassemblies called modules created independently and then used in different systems. The primary objective of using modularity is to achieve more independent component groups through dividing a system into physical modules that are subsystems or product components. In this paper, an educational application was developed using a modeling method to analyze the system by highlighting design information, including: components, requirements, functions, subfunctions. Matrices provide a means of modeling the relationships between the design and analysis domains of the system using mathematical functions. The modelling method is demonstrated in developing and improving a manual wheelchair by making an application in Matlab Software, that analyzes connected information domains.

1. Introduction

A product development process includes the set of activities needed for a product concept to reach the market. For the effective development of a product, it is necessary to build product from customer needs analysis and information sequence, to subsequent feedback. A design process includes the entire set of technical activities within a product development process that work to meet the marketing requirements. An approach for developing a new product can be a modular design that subdivides a product into smaller subassemblies called modules created independently and then used in different systems. Modularity is a popular research topic and many authors have reviewed its different applications. Baldwin [1] defined modularity as a methodology to divide a design into segments to ease the management of a complex system. Dahmus [4] categorized a product module as a subsystem within a product. There are also process applications of modularity but only for modelling purposes. Breidert [2] proposed an approach for the synthesis of modular systems, based on structures and modules on different levels. Eppinger et al. [5] captured the design tasks during the product development process with the Design Structure Matrix and applied advance simulations to generate project schemes. Pahl and Beitz [9] were the first in modelling all engineering processes with a functional based approach using energy, signal and material flow. Stone extended Pahl and Beitz's technique and proposed a theory of modularization by using functional modelling as the repeatable basis for the decomposition of a product [10]. Yang et al. [11] conducted a survey to study several enterprises approaches of modularity which led to the conclusion that they have their own



interpretations of modularity and their own distinct motivation for integrating modularity into product development.

2. Modelling method

The method proposed by Mosho [8] sets the following activities and steps for developing and modelling a product: requirements modelling, function modelling, component modelling, test measurable modelling, analysis of requirement and functions, analysis of functions and components, analysis of components and technical characteristics, requirements to component analysis, requirements to assembly analysis, function to assembly analysis, requirement to engineering characteristic analysis. In this paper based on the algorithm proposed in [8], a Matlab software application was developed to solve the structure of a manual wheelchair. The design of a manual wheelchair was chosen because is quite simple, which allows the use of the next analyzes to develop and to improve it with the possibility of attaching and detaching a system that allows transformation into an autonomous mobile product, without adding to the overall dimensions and offering the ability to maintain the stability of the wheelchair.

2.1. Assembly-Component Decomposition

The technique of physical decomposition breaks down the product into component sub-assemblies and develops product structure. It is used as modelling technique for product architecture for products where changing a part of a product can have multiple impacts on other modules. The advantage of this breakdown is that the components of a product can be physically analyzed. The concrete elements of a constructive structure must meet the necessary requirements for a technical system to function properly. The functional structure presented in figure 1 was performed using reverse engineering through discovering the technological principles of the product and analyzing its structure and function [7].

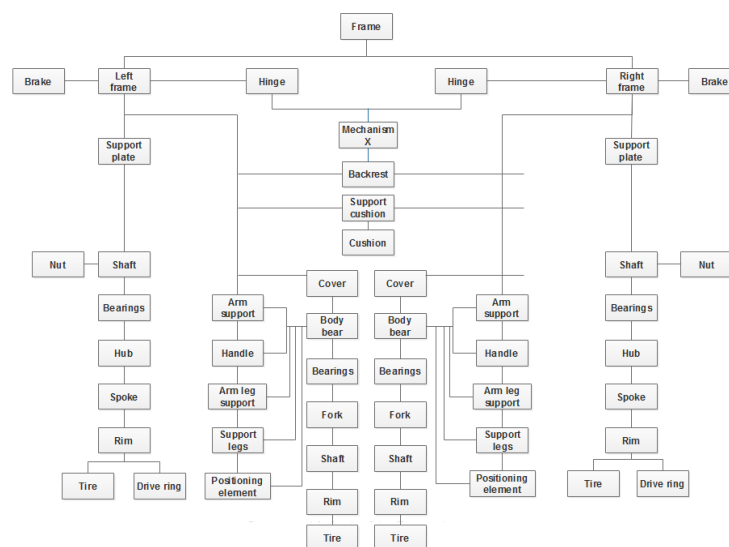


Figure 1. Components of a manual wheelchair.

Starting from this structure, the subassemblies and their components are introduced into the proposed application. The end of this stage is represented of filling out the matrix subassemblies-component by adding 0 and 1. The value of 1 is placed at the intersection of the line corresponding subassemblies to the columns for components. The steps for completing assembly and components data are presented below.

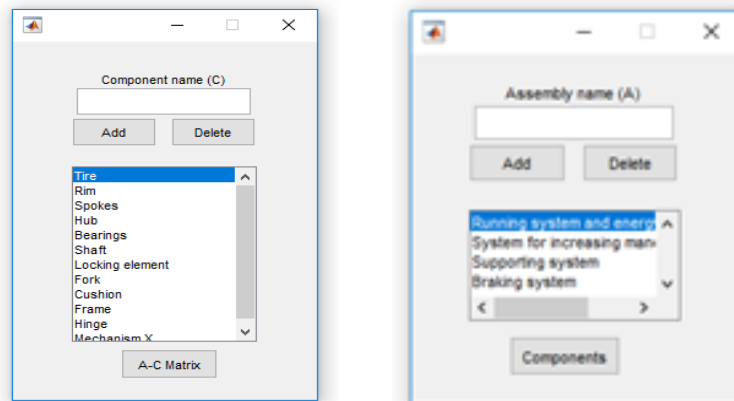


Figure 2. Introduction of input data for components and assembly.

2.2. Function and Subfunction

The analysis of the general function of the product will lead first and foremost to determining the main functions and then the secondary functions. The main functions are attributes of the product that determines the general function. The secondary functions result from the interaction of the main functions and from interactions between the main functions and the environment in which it is developed. The functionality of the product is determined through developing a function structure. Using overall functions, the decomposition of the product into function modules is significant. In a functional approach, an overall product function refers to a general input or output relationship of a product overall task, which is described in a verb-object form and represented by a black-boxed operation on flows of materials, energies, and signals. A subfunction is also described in a verb object form but represented by a basic operation on defined basic flows.

Function modules help to implement technical functions independently or in combination with other functions. Based on the constructive structure, the functions and subfunctions for the product studied in this paper are established.

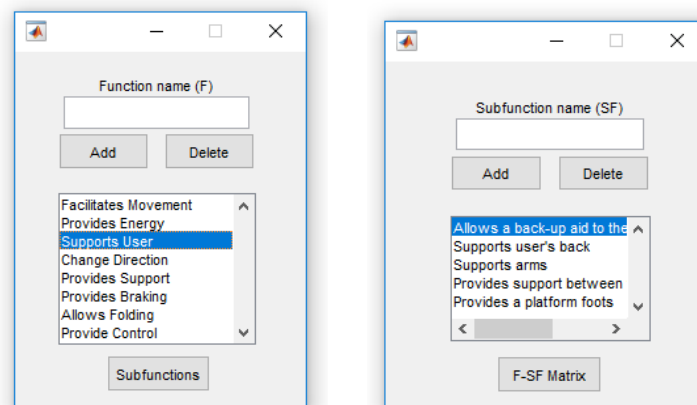


Figure 3. Function and subfunction data.

At this stage, as a result of using the software, using the same input methodology, this time, for functions and subfunctions, the F-SF matrix results. The value of 1 is put at the intersection of the line corresponding to the function with the columns corresponding to the subfunctions. Verification of links between functions and subfunctions is done in the application by the appearance of a check mark when a subfunction influences a function.

	1.1	1.2	1.3	2.1	2.2	4.1
1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
5	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure 4. Function-Subfunction Matrix.

2.3. Analysis of Requirements and Subfunctions

For determining the mutual influence between requirements and subfunctions, the scale of Saaty is used in establishing the weights of each criterion considered. This scale consists of 9 points which has the following score: 1 = equal importance, 3 = moderate importance, 5 = strong importance, 7 = very strong importance or proven importance, 9 = extrem importance. 2,4,6,8 are grades that are not commonly used. The list of requirements for the wheelchair was done using the literature review and is shown in figure 5.

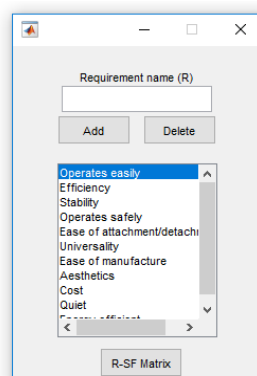


Figure 5. List of requirements.

Using Saaty's scale, the application proposes an interface that shows on the line the requirements and the subfunctions on columns, leaving the user the ability to set the score. The weight is determined, the total score is calculated on the column and then on the line. The values in the column are used to establish the requirements hierarchy. The classification of each requirement is very important because it separates the system requirements and allows the individual requirement to be weighed. This type of analysis gives the designer the ability to determine what functions are important in developing a product [8]. In the following figure, association matrix requirement-subfunction is presented to analyze how a requirement is related to a subfunction.

	1.1	1.2	1.3	2.1	2.2	4.1
1	5	5	5	5	5	5
2	5	5	5	5	5	5
3	5	5	5	5	5	5
4	5	5	5	5	5	5

Figure 6. Requirement-Subfunction Matrix.

2.4. Analysis of Subfunctions and Components

At the next step of the analysis, similar to the previous subchapters, it is used the same procedure, the SF-C matrix is completed, using 0 and 1 values to show the bond between component and subfunction. It is marked with 1 cell in the array if a component influences the fulfillment of a function, otherwise the field will be filled with 0. It is important to determine the functionality of the components in the system and then to analyze it in terms of functional clusters. The SF-C matrix provides a means of determining component functionality individually. Functional components are determined by summing the column elements without taking into account the hierarchy of each function [8]. The importance of each component is related to the functions that are accomplished.

2.5. Requirements to Component Analysis

The matrix requirement-component is obtained by multiplication between requirement-subfunction and subfunction-component that are established in the previous points and is presented in figure 5. This stage shows the degree of influence between the requirements and the components. The R-C matrix reveals supplementary information including how strongly or weakly a requirement is related from a functional point of view to a component in the product. From the R-C matrix presented in figure 7, ordering the sum from rows and columns, the importance of requirements and components is determined.

	1	2	3	4	5	6
1	28	35	14	14	21	7
2	5	10	0	10	5	10
3	0	1	1	2	3	1

Figure 7. Requirement-Component Matrix.

2.6. Requirements to Assembly Analysis

The requirements-to-components matrix and assembly-component matrix obtained in the previous paragraphs are multiplied, arriving at the requirement-to-assembly matrix. The R-A can determine how strongly requirements are related to a group of parts. The values presented in the R-A matrix are not necessarily influenced by individual functionality, but by considering the operation of all elements.

The result of the column sum determines the most important subassemblies. In this manner, it can be determined what if a requirement has a greater influence over the others within a subassembly. From the analysis carried out, the great importance of the maneuverability and energy efficiency requirements, leads to finding more constructive solutions for the improvement of the components of a manual wheelchair. For example, wheels, bearings and frame are components with great influence on product functionality. Contrariwise, cushion is a low critical component because it does not affect the fulfillment of the main functions of the product.

3. Conclusion

The method used is an useful tool in designing a product new or improving an existing one. With this method, the designers will manage to separate the effects of functional and physical decoupling. Optimizing solutions should take account of requirements and restrictions imposed by materials, technical, economic, legal, environmental considerations. These analyses allow designers to define the most important properties in the system. The following types of analysis are completed through: grouping elements that are linked, associations between various domains of informations through matrix operations. The software warns the user that the process can not continue when the respective matrices can not multiply due to non-fulfillment of conditions. The Matlab application has an

educational purpose, being used in product development and product design courses and will be improved by feedback from users.

4. References

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