A Method Based on Functional Reconstruction of Product Innovation Design

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Abstract. The purpose of product innovation design is functional innovative, and the functional reconstructed could be able to change the combination between product functions. First the product functional activities is used for functional modeling, then the model is checked with principles of functional modeling, After reduced functionality of the checked functional modeling under reduction rules, the function is expanded with expansion principles, Finally the new functional model is optimized with functional constraint, in order to build new products functional model and get product innovative solutions.

1. Introduction

Product design process is based on the function of the design process, otherwise known as driven by functional design process, the ultimate goal of product innovation design is functional innovation, which is a optimize and updating of the function and structure of the product process driven by demand and technology. Function is the most basic element in the product concept design, product design can be seen as a function of the realization of the process, namely the functional design, functional design research the mapping method of function-behavior-structure and the solution process[1-2]. Product innovation can be seen as a function transformation process, ie, functional innovation, functional innovation focus on the method of transformation of functional components: Tan et al.[3] proposed an innovative ideas integrated needs evolution and function evolution, the process of product function evolution be described by using biological function evolution. this paper raised some evolutionary strategies such as function expansion, integration and bundled; Ma et al.[4] advanced an evolution-driven method of product innovation, adopted the evolution strategies of self-cross, different-cross, positive-variation, negative-variation and self-variance operated on function components; Sun et al.[5] constructed a product innovation model based on function incentive, used functions related, functions transform, function remove as a strategy which operated on sub-function; Wan et al.[6] proposed a product innovative method based on endogenous function requirements, innovative process was incentived by function matrixes, function rimming, function combination et al.

The above method is based on the functional structure tree, focusing on the transformation in the form of functional components. Functional structure tree can clearly express the level structure of product function, but lack of consideration of the mutual activity relationship between the function and the study did not break through the existing product functionality framework, and will function as a single attribute, thus support a limited degree of product innovation. This paper established a product innovation method based on function reconstruction, product function activities was used for functional modeling on existing products, then the model is checked with principles of functional
modeling. After reduced functionality of the checked functional modeling under reduction rules, the function is expanded with expansion principles. Finally the new function model is optimized with functional constraint, in order to build new products functional model and get product innovative solutions.

2. Functional Activity Modeling

For a technical system or product, the function performance characteristics of the system with the conversion of energy, materials, information, or other physical quantities, i.e. the relationship between the amount of input and output of the technical system, the function can be abstracted as an input and output nodes, Figure 1 is the diagram which a technical system is abstracted as a function node.

![Fig 1. The diagram of system function abstracted as function node](image)

In order to find a solution to meet product function in design process, function analysis methods of top-down or bottom-up were adopted. Top-down functional analysis makes complex product function decompose into simple sub-functions, and the product's function and the linkages between functions is described, function was arranged in accordance with the logic and the priority order, in order to understand the affiliation between function of product, the main analytical methods contain Functional Analysis System Technique, functions method tree, FBS functional decomposition method; Bottom-up functional analysis starts from the bottom of the system, and finds the internal relationship between the various components of the system and ultimately establishes function structure of the system, the main method is component-based analysis methods and so on. Based on the functional analysis and modeling tools, considering the mutual relations and mode of action, functional activity diagram was used for function modeling, the main modeling elements of activity diagram is shown in Table 1.

![Table 1. The modeling elements of functional activity diagram](image)

Under the above modeling elements, the four basic model structures is constituted in functional activity diagram, i.e. serial structure, parallel structure, selection structure and iterative structure, as shown in Fig 2. Serial structure of Fig 2-1, functions are running with the sequence of execution, the follow-up functions requires the previous function of the output information as input; Parallel structure of Fig 2-2, some functions are running at the same time without the exchange of information; Selection structure in Fig 2-3 makes a choice between two or more functions; Iterative structure in Fig 2-4 represent the function is executed several times.

![Fig 2-1. Serial structure](image) ![Fig 2-2. Parallel structure](image)
3. Functional Mode Checking

Because the build functional activity diagram of the product may conflict or interfere, functional mode checking used for eliminating errors is very important. The conflicts and interference comes from two aspects: (1) Physical conflict, which is caused by incorrect description of the problem domain in the process of functional analysis, the solution of this problem requires the relevant experts in the field to provide support; (2) Semantic conflict, which is made mistake by utilizing methods and tools of functional modeling, it is always caused by the logical errors of the active node, the solution of this problem requires re-analysis the modeling process. However, semantic conflict is not derived from the product's function, therefore this paper consider physical conflict. Several common errors of physical conflict are as follows:

3.1. Functional deadlock.

After the execution of the F1, the next execution is any one of F2 or F3, but after the execution of F2 or F3, the execution conditions of F4 has never been met, thus F4 became a deadlock node. The unlock methods of deadlock structure include functional decomposition and functional replacement and so on.

3.2. Functional infinite loop.

After the execution of the F1, the next execution is cycle of F2 or F3, because after F3 is a ‘and - co’ structure, F2 is always executed and can’t be stopped. The unlock methods of functional infinite loop include functional decomposition and functional replacement and so on.

4. The function simplify and expansion

After Functional Mode Checking, the functional activity diagram without correct should clearly reflect the functional structure of the existing product, the next to do is achieve product innovation through product functional reconstructed. this paper is mainly achieved through the function simplify and expansion. Function simplify is focused on the four basic structures in Fig 2, Mainly include:

Serial simplify. Find the sequence structure of F1, F2 in the functional activity diagram, and simplify the sequence structure of F1, F2 as a virtual node O12, O12 is represented as a virtual serial nodes; Parallel simplify. Find the parallel structure of F1, F2 in the functional activity diagram, and simplify the parallel structure of F1, F2 as a virtual node P12, P12 is represented as a virtual parallel
nodes; Select simplify. Find the select structure of F1, F2 in the functional activity diagram, and simplify the select structure of F1, F2 as a virtual node S12, S12 is represented as a virtual select node.

Iteration simplify. Find the iteration structure of F1, F2 in the functional activity diagram, and simplify the iteration structure of F1, F2 as a virtual node I12, I12 is represented as a virtual iteration node.

Function expansion should follow the principle of: The shortest time principle, the shortest time in the reconstructed functional activity diagram, the higher the efficiency. The shortest path principle, the shortest path in the reconstructed functional activities can reduce the complexity of implementation of the function; The least resources principle, the least resources in the reconstructed functional activity diagrams need external resources least, so as to reduce the energy consumption.

5. Process of Product innovation design based on functional reconstruction

Product innovation design process based on functional reconstruction is shown in Fig 5. The process begins with user requirements analysis and design problem representation, through analyzing and modeling of existing product, functional activity diagram of existing product is obtained. After function simplify and expansion, functional activity diagram of new product is obtained, and use FBS mapping resulting innovation program, through solutions optimization, the best solution was came out.

![Fig 5. Process of Product innovation design based on functional reconstruction](image)

6. Conclusions

Based on the functional activity diagram, this paper established a method of product innovation method based on functional Reconstruction, this method can effectively achieve the functional reconstruction of the products, resulting in the functional model of the new products. The method was proved to be very effective in the multi-functional wheelchair innovative design. Due to space restrictions, multi-functional wheelchair innovation in the application of the method will be described in other papers.

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