Title:
Function Integrated Product Innovation Based on Laws of Need Evolution

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Introduction:
Competitiveness of a product can be improved by the function innovation to meet the market change [8]. Function integration is one of the important tools for the product innovation. More and more articles on the topic of function integration. Lin et al. [5] introduced a concept of the product function integration, innovative techniques, and their influence on enterprises. Li et al. [7] proposed a process model of the function integration for product innovation from the functional design level. Liu et al. [6] proposed a method of bio-inspired design of multiscale structures for function integration. Liu et al. [4] proposed a process model of product innovation design based on the function combination and TRIZ. However, most of the existing methods of the function integration focus on technical elements and their impact on enterprises. They are subjective and fuzzy in identifying needs and searching solutions, which is difficult to be used in the function integration for product innovation. Laws of need evolution [9] in TRIZ suggest the direction of product evolution to predict potential user needs, including idealization of needs, dynamization of needs, coordination of needs, integration of needs and specialization of needs. Strengths-weaknesses-opportunities-threats analysis (SWOT) [3] considers internal and external perspectives to evaluate strengths, weakness, opportunities and threats of functions and other issues of product development. Laws of need evolution and SWOT can predict and classify user needs for innovative product design. Meanwhile, function similarity [1] can be used as a measure to select the integrated function products. In this paper, an integrated product functions method for innovation is proposed. Laws of need evolution and SWOT are used to determine needs of the target product. Integrated function products are determined by searching patents and product similarity to meet the needs. The product solution is proposed by using TRIZ tools. The innovative design scheme is searched according to the priority degree evaluation [2]. Feasibility of the proposed method is verified by the innovative design of a cleaning device of the oil sump in a range hood.

Main Ideas:
Function integration combines product functions for the function multiplication or function emergence of the product, which pays more attention to meeting potential needs of users. As the change of the needs is regular, correctly predicting potential needs can enable enterprises to obtain business opportunities and develop products that meet the needs of users. This paper uses laws of need evolution and SWOT to identify the need of the target product. Fig. 1 shows the needs forecasting and classification model based on SWOT. Needs are sorted in following four categories by applying the

SWOT. (1) W: The disadvantage area of the enterprise. (2) S: The advantage area of the enterprise. (3) O: The opportunity area of the enterprise. (4) T: The threat area of the enterprise.

The integrated function products are decided by searching similarity of existing products. The total function of the products is used to determine the function keywords, construct the corresponding retrieval formula for the patent retrieval, and decide preliminarily plans of the integration. The functional tree of the product and the similarity searching are introduced to select top products as references for the function integration. The similarity between two products is decided by Eqn. (1). If product A and product B have similar sub-function *j*, and their weights are $w_j(A)$ and $w_j(B)$, respectively, then

$$S = s_j = \frac{\min\{w_j(A),\ \ w_j(B)\}}{\max\{w_j(A),\ \ w_j(B)\}},\ \ 1 \geq s_j \geq 0 \qquad (1)$$

If product A and product B have N similar sub-functions, then

$$S = \frac{N}{K + L - N}\sum_{j=1}^{N} s_j \bullet w_j,\ \ j = 1,\ \ 2 \cdots N \qquad (2)$$

where K and L are the number of sub-functions of an existing product and the integrated function product; N is the number of similar sub-functions between them; w_j is the weight of the sub-function affecting product similarity. $w_1 + w_2 + \cdots + w_N = 1$; s_j is the similarity of similar sub-functions.

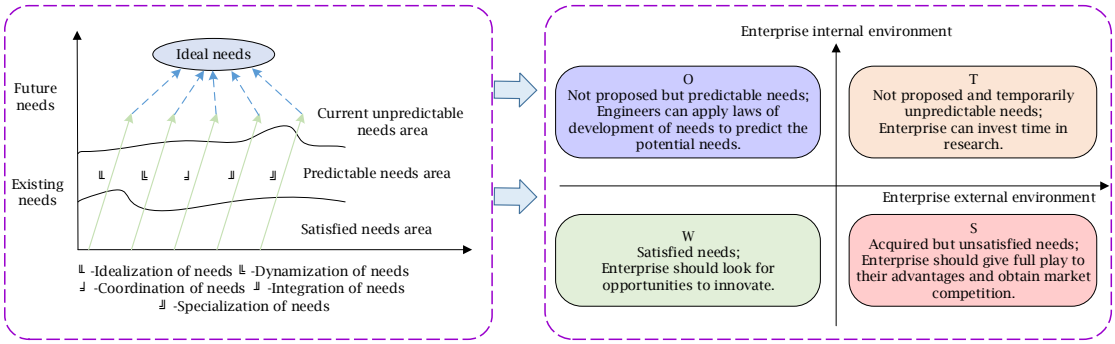


Fig. 1: Needs forecasting and classification based on SWOT.

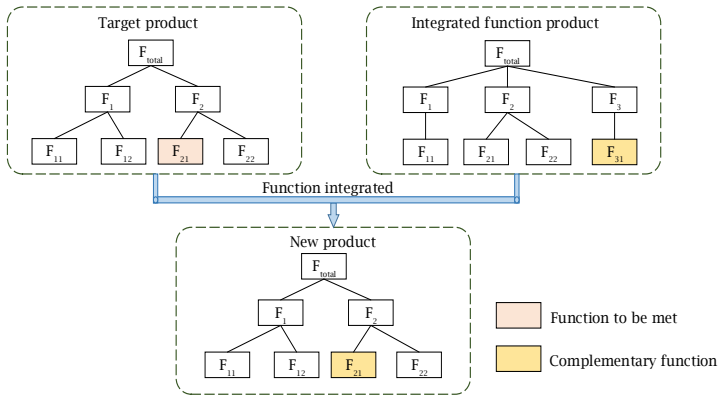


Fig. 2: Function integration process of existing product and integrated function product.

Function integration combines several functions for the total function of a product. Functions of two products are integrated to meet of the target product as shown in Fig. 2. TRIZ tools are used to search invention solutions of the preliminary scheme. The innovative design scheme can be finally developed by the priority degree evaluation. The process of the product function integrated innovation based on laws of need evolution includes 4 steps: (1) Identifying the target needs; (2) Identifying integrated functions; (3) Function integration; (4) Solution evaluation as shown in Fig. 3.

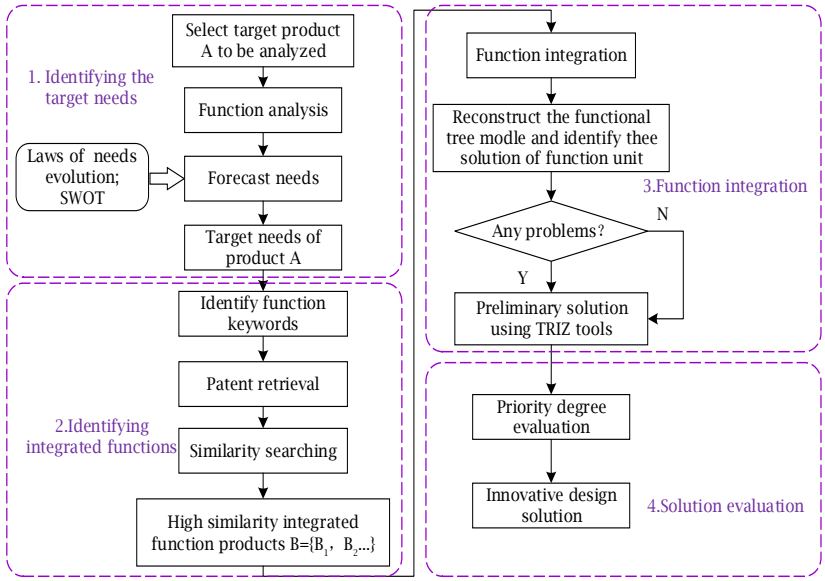


Fig. 3: Product function integrated innovation process based on laws of need evolution.

Case Study:

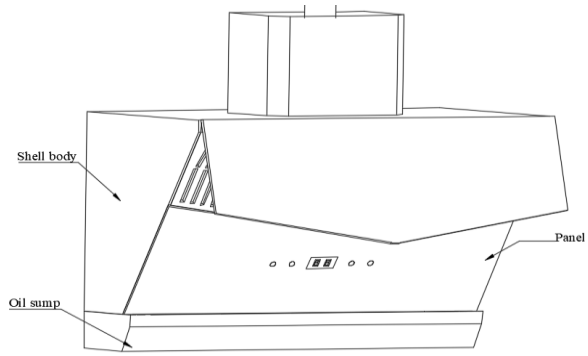


Fig. 4: The structure of a range hood.

Fig.4 shows the structure of a range hood [11]. During using the range hood, the oil stain is accumulated in the oil sump which needs to be cleaned. However, the existing method of cleaning is to remove the oil sump for cleaning, which is inconvenient for users.

According to laws of need evolution and SWOT, main needs and target needs of the oil sump cleaning system of the range hood are identified as shown in Tab. 1. The integrated function products are obtained by the patent retrieval as shown in Tab. 2. According to the similarity searching, products with integrated functions are determined as “An electrostatic oil fume purifier” and “Fiber removing device in wet electrostatic oil fume purifier”.

Number	*Needs*	*Identified needs of the oil sump cleaning system*
1	Increase diversification	It is mainly aimed at the heavy oil in the oil sump
2	Improve quality	Good cleaning effect
3	Decrease time	Reduce cleaning time
4	Reduce harmful actions	No pollution
5	Reduce human intervention	High automation of cleaning system
6	Strong adaptability	The cleaning system is adapted to the sump
7	Coordination	Cleaning system process coordination
8	Rationalization	The cleaning system process is reasonable
9	Multi functions	Both cleaning and monitoring functions
10	Multi needs	Cleaning and monitoring needs are met
11	Strong pertinence	It is mainly aimed at the oil stain in the oil sump

Tab. 1: Needs identification of the oil sump cleaning system.

Number	*Integrated function products*	*Patent number*	*Similarity*
1	An electrostatic oil fume purifier	CN111111927A	0.7272
2	An integrated stove with oil fume purification device	CN109708173A	0.5294
3	An automatic cleaning device for waste gas discharge filter	CN107213711A	0.6667
4	An automatic oil fume pot cover for removing oil stain on filter	CN104873110A	0.5385
5	Fiber removing device in wet electrostatic oil fume purifier	CN104645738A	0.6981

Tab. 2: Integrated function products based on similar searching.

In addition, functional trees are built to model the range hood and two integrated function products as shown in Fig 5. (Only one integrated function product is shown as the page limit). On this basis, the range hood is integrated with the proposed product for a function tree of the new product as shown in Fig 6. The innovative design scheme is obtained by TRIZ tools and the priority degree evaluation as shown in Fig 7. A liquid level detector is installed in the oil sump to control the cleaning time. The heating tube is set in the scraper to achieve the cleaning effect. Therefore, the design is simple in structure for automatic cleaning of the oil sump.

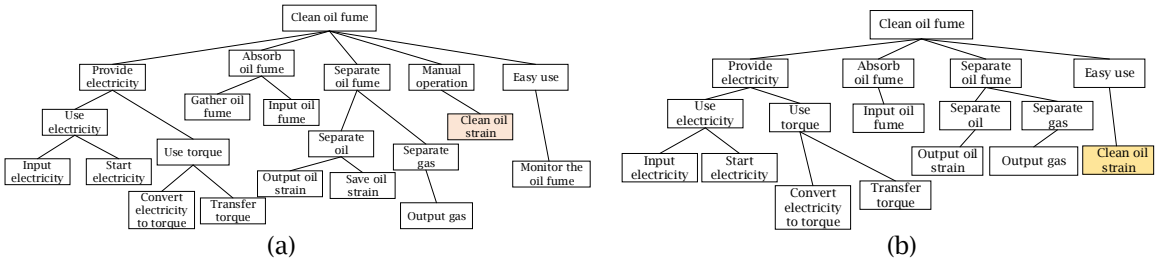


Fig. 5: Functional tree models of range hood and integrated function product: (a) Functional tree of the range hood, (b) Functional tree of the electrostatic oil fume purifier.

Conclusions:

A method is proposed for the function integrated product innovation. The laws of need evolution and SWOT are applied to decide target needs of a product. Integrated function products are decided by similarity searching. The proposed method is verified in the innovative design of a cleaning device of the oil sump of the range hood.

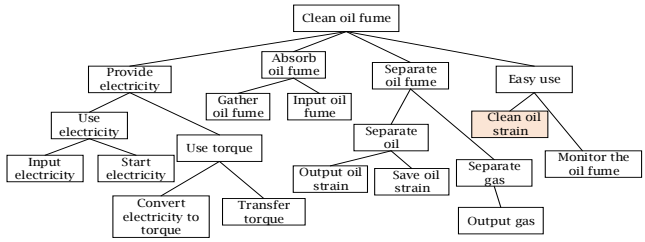
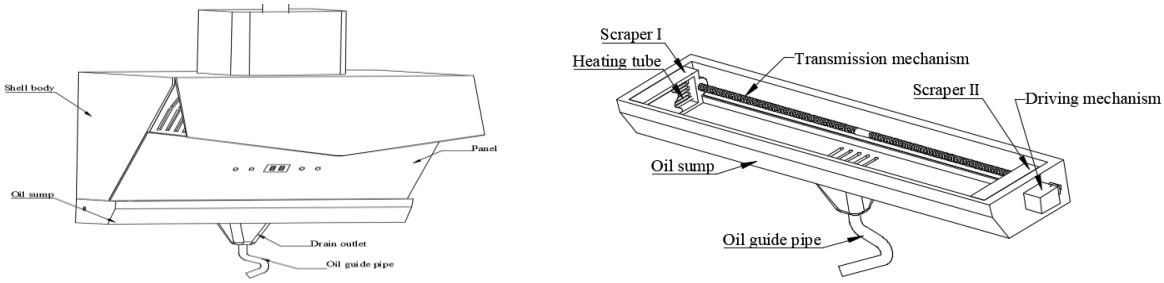


Fig. 6: Functional tree model of new product.



(a) (b)

Fig. 7: Innovative design scheme of the range hood: (a) Overall diagram of the range hood, (b) Overall diagram of the oil sump.

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