Title:
Personalized Agile Innovation Process Model Based on CAD

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Introduction:
With the development of the knowledge network economy, the in-depth integration of innovative design and new technology has injected new momentum into the sustainable innovation and development of enterprises, which has become a new driving force leading the industrial revolution [2]. Progress in information technology and production technology encourage the realization of personalization [1]. After entering the 21st century, product competition has intensified. The user's demand for personalized products is becoming stronger. Therefore, a new design method is urgently needed to meet the personalized and agile design of new products. Knowledge mining is an important tool for personal product design knowledge acquisition. The innovative design of personalized products is mainly designed from the functional level. The design of functions requires a variety of knowledge, even cross-industry and cross-disciplinary knowledge is a resource for problem-solving. However, there is very little knowledge that can be used directly, which brings great difficulties to the design of personalized products.

In summary, this article proposes a new design process model that combines functional design and computer-aided design technology to solve the shortcomings of existing methods. Firstly, the designer analyzes the user's personalized demand and uses functional analysis to decompose the new product. And the designer establishes the functional structure of the new product in a functional-based language. Secondly, the designer constructs a search strategy to abstract the function into search keywords so that it can be searched in the functional structure and functional model library extracted from the patent. The designer then obtains the functional structure and functional model of similar products. Then the designer uses the functional similarity matrix to quantitatively screen the patented products to obtain the most matching functional model. Finally, the designer uses the TRIZ tool to establish a functional model of the new product and obtain the final engineering design plan.

CAD-based functional structure and functional model library establishment:
New product development or introduction of new system functions is an important component of product innovation design. In the development of new products, a few products are brand-new designs, and most of them reuse existing components or modify past parts and components. Many product designs have achieved product innovation by learning from similar products. The computer-aided innovation software developed in this paper is designed according to the connection relationship between the components clearly in the patent text. The patent has the following connection relationships, such as "The element 1 is connected to the element 3 through the element 2". According to this connection relationship, the information in the patent text is extracted into the form of a functional model. Then, according to the functional relationship between each element in the functional model, the designer analyzes the functional role of each element and establishes a

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functional structure. We access the functional structure and functional model into the software database to provide designers with search for similar products. First, the function description is performed, and then the simplest form of subject + predicate + object in the function description is extracted, and the patent library is determined. Then the designer can identify similar products based on the similarity between the functional structures after the standardization of the functional base and provide help for the innovative design of new products. The software is equipped with a calling function, and the functional model and functional structure of the new product are input into the database. This function can meet the increase and expansion of the database, and it can provide more design solutions for the design of new products in the future. For example, if we input a workpiece sorting device, the software will automatically output a knowledge base of multiple types of workpiece sorting products as shown in Figure 1.

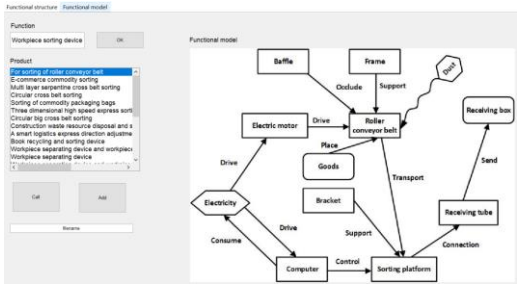

Fig. 1: The functional model of software for workpiece sorting device.

CAD-based Similar product function analogy process:

In order to find similar products easily, we use the method of functional similarity matrix [3],[4]. Through the quantitative comparison between the functions of the newly designed product and the functions of the existing products, the product with the highest similarity is selected to assist in the subsequent product design. The standardized formula calculation is shown in formula (1).

$$N_{ij} = \phi_{ij}\left(\frac{\overline{\eta}}{\eta_j}\right)\left(\frac{\mu_j}{\overline{\mu}}\right) \tag{1}$$

N_{ij} represents the i-th function of the j-th product in the matrix N, ϕ_{ij} represents the i-th function of the j-th product in the matrix ϕ, and $\overline{\eta}$ represents the average value of the elements ϕ_{ij} in the matrix ϕ, and the calculation formula is as shown in (2). η_j represents the function weight sum of the j-th product, and the calculation formula is as shown in (3). μ_j represents the sum of the weight values of the elements in the canonical matrix H,as shown in (4). $\overline{\mu}$ represents the average value of all elements in the canonical matrix H, as shown in (5).

$$\overline{\eta} = \frac{1}{n}\sum_{i=1}^{m}\cdot\sum_{i=1}^{n}\phi_{ij} \tag{2}$$

$$\eta_j = \sum_{i=1}^{m}\phi_{ij} \tag{3}$$

$$\mu_j = \sum_{i=1}^{m}H(\phi_{ij}) \tag{4}$$

$$\overline{\mu} = \frac{1}{n}\sum_{i=1}^{m}\cdot\sum_{i=1}^{n}H(\phi_{ij}) \tag{5}$$

The normalized matrix H is mainly to eliminate the subjectivity of user requirements and reduce the complexity of functions. H_{ij} represents the i-th function of the j-th product. When the required function exists in the product, it is assigned a value of 1, otherwise it is 0, as shown in (6).

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$$Hij = \begin{cases} 1 & \text{When function in the jth product } i \neq 0 \\ 0 & \text{When function in the jth product } i = 0 \end{cases} \quad (6)$$

According to the calculation formula of the functional similarity matrix, the designer uses MATLAB tool to process the data, and the interface of the data processing is shown in Figure 2.

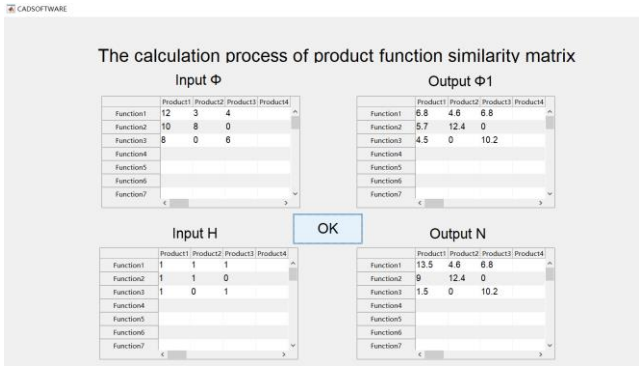

Fig. 2: The functional model of software for workpiece sorting device.

CAD-based personalized agile innovation design process model:

Figure 3 is a CAD-based personalized agile innovation design process model. The steps are as follows. First, the designer conducts a demand analysis. Second, according to the results of the demand analysis, the designer determines the overall function of the product and performs functional decomposition. Third, according to the result of functional decomposition, the designer establishes the functional structure of the new product. Fourth, according to the total function analysis, the function model and function structure of similar products are found through computer-aided innovation software. Fifth, the designer makes functional analogy through the functional similarity matrix to find similar products. Sixth, the designer combines resource analysis and functional trimming tools [5] to obtain a preliminary functional model. Seventh, according to the conflict analysis tool in TRIZ, the inadequate and harmful effects in the system are eliminated. Seventh, according to the conflict analysis tool in TRIZ, the deficiencies and harmful effects in the system are eliminated, and the functional model of the new product is used for innovative design.

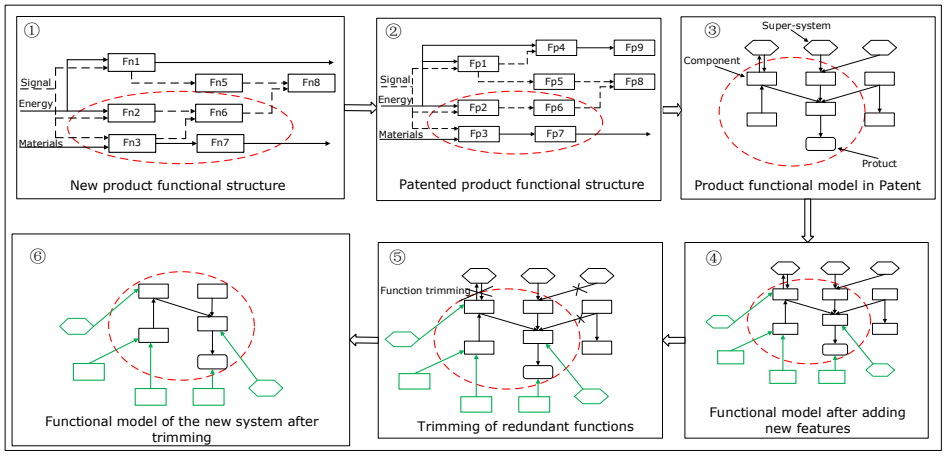

Fig. 3: CAD-based personalized agile innovation design process model.

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Design of natural wind dust removal system for solar panels:

First, the designer establishes the functional decomposition and functional structure of the solar panel dust removal system, as shown in Figure 4 and Figure 5. Then the function structure and function model of similar products are found through computer-aided design software, as shown in Figure 6. And the most similar products are found according to the functional similarity matrix. Finally, according to the functional model of similar products, the functional model and the three-dimensional model diagram of the solar panel natural wind dust removal system are established as shown in figure 7.

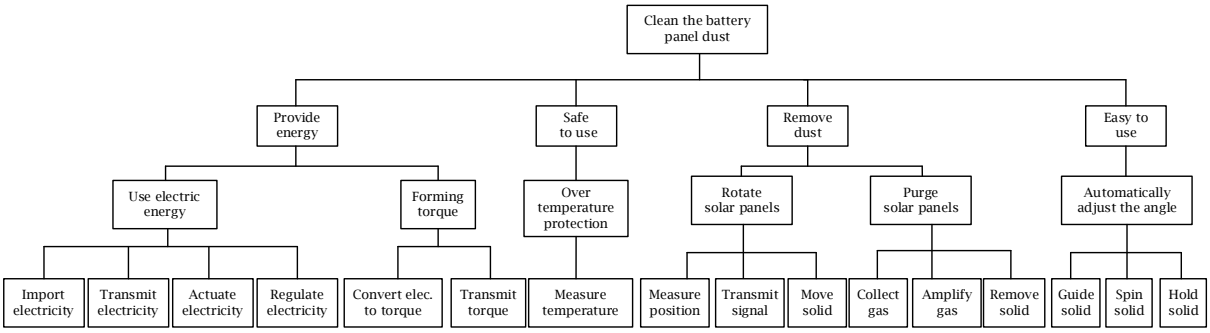

Fig. 4: Functional decomposition diagram of solar panel dust removal system.

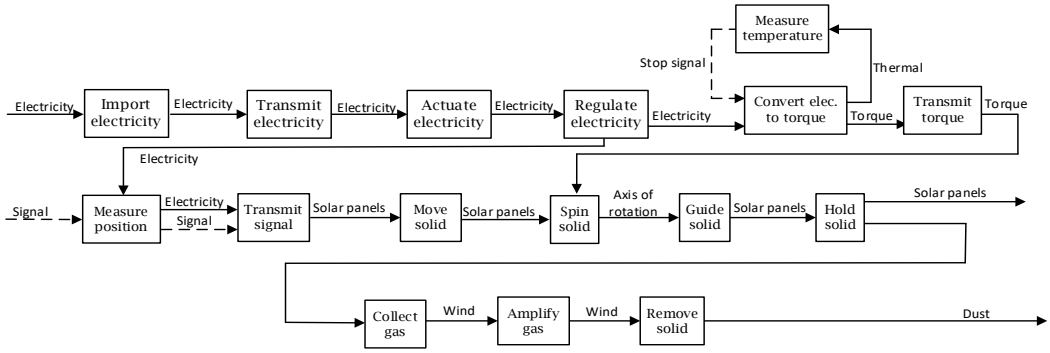

Fig. 5: Functional structure diagram of solar panel dust removal system.

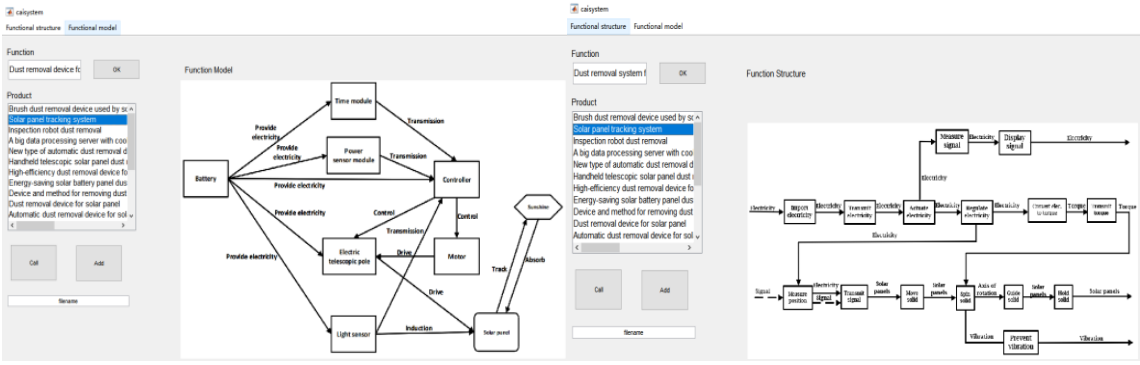

Fig. 6: Left：Similar product function model；Right：Similar product function structure.

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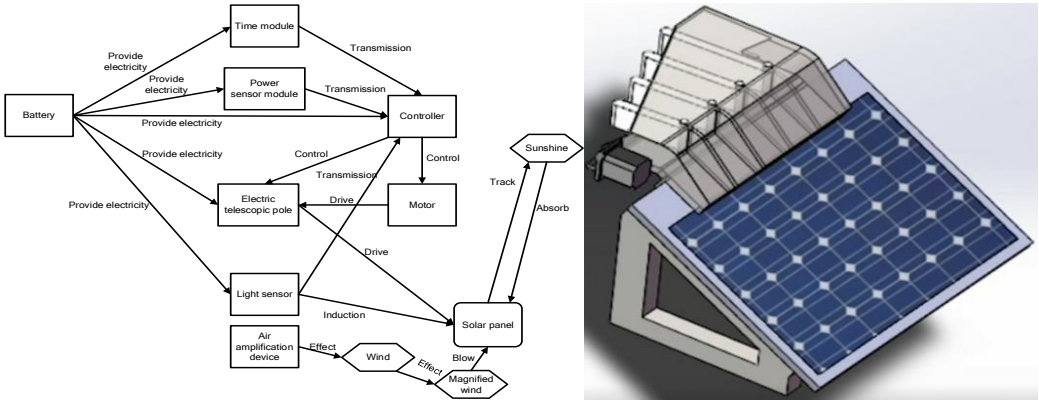

Fig. 7: Left：Functional model of natural wind dust removal system；Right：3D model diagram.

Conclusion:

This article uses computer-aided innovation technology and functional analysis to integrate, which researches out a construction method that meets the rapidity and agility of new products. This model has the following advantages:

1. Satisfy the rapidity and agility of personalized customization of new products.
2. The functional model of similar products is used to assist in the innovative design of products, which shortens the design cycle.
3. Through the functional model and functional structure in similar patents, the harmful and insufficient effects are less, and the new product design is more accurate and reasonable.

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