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Modularization of product service system based on functional requirement

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Abstract

The customers need no longer just a physical product, but rather the required function provided by the offering of product and service, namely product service system (PSS). Modularization plays a key role in the PSS development in order to address and support individual conceptual design. Functional requirements of PSS can be identified and then classified into different clusters by using a fuzzy clustering algorithm. Considering the relationships between the products and services in a PSS with functional requirement clusters, PSS can be clustered into several modules. Through the modularization, PSS can be easily to customized design for meeting individual requirements. A numeral control machine case is used to show the validity and feasibility of the proposed method.

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Keywords: Product service system(PSS); Modularization; Functional requirements; Fuzzy clustering

1. Introduction

Product Service System (PSS), as one of main development direction in the manufacturing markets, aims to provide from just a physical product to a result or a function offered by leveraged product combining with corresponding services jointly to meet customer requirements [1, 2]. Aurich et al. [3] used a process library to select, combine, and adapt the appropriate modules. Mannweiler et al. [4] used a standardized method framework to describe the interface of the product and service modules. Yicong et al. [5] proposed the considerations of not only the traditional function related attributes, but also the maintenance related ones. The structure of PSS is composed of a series of different types of physical modules and service modules, where is necessary to identify proper module partition for facilitating PSS customized design. The relationships among PSS modules are more complex and mixed [6]. According to these complex relationships, PSS can be modularized and then configured based on personalized physical structure and service model to better meet customer requirements [7]. Modularization can reduce the number of modules by diversifying PSS internal module combination, which helps to reduce production cost and environmental impact and realize sustainable development [8, 9].

Modular design can not only improves the response speed of PSS and consequently meet individual requirements, but also greatly improve stakeholders profits, including customer, manufacturer, servicer, environment, and so on. Modular design method has its own unique performance in the analysis of product composition mode, mechanism optimization and system decomposition, reorganization and coordination. There are a large number of relevant literatures on product and service modularization. Piran et al. [10] analyzed the causal effects of product engineering efficiency and production processes to modularize the product and demonstrated that product modularization can significantly improve efficiency and productivity. Taking into account the complex modular products, Fan et al. [11] proposed a modular product platform model, which was based on the breadth first search, and constructed the modular structure of product family. Li et al. [12] made use of the weight of the complex network to modularize the product system. Li et al. [13] described the

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modular structure modeling of complex integrated service-type mechanical products. By discussing the fuzzy relationship between product service and functional requirements, the modularization of product service can be integrated on the basis of functional requirements modularization [14].

From function aspects, functional requirements of PSS are easily identified by customers and design engineers. The products and services in PSS are connected with the functional requirements separately. Deng et al. [15] used ant colony clustering algorithm for module partition. Asok et al. [16] put forward the module partition method based on graph theory and fuzzy logic, which is defined as the process of selecting the best module to divide the seam position. Cheng et al. [17] used the design of the structure of the matrix module division method, through the module of the product matrix calculation to obtain module partition program. Li et al. [18] proposed a method of product module clustering based on Rough Set. All of these elaborated separately the product modularization or the service modularization, and lacked the discussion of the integration for the product service. The functional requirements are clustered by using a fuzzy clustering algorithm. Through these established relationships, all the constituent components of PSS can be classified into proper modules. Section 2 describes the module division principle of PSS. Section 3 proposes PSS modularization method using functional requirements. Section 4, a numerical control machine case is used to illustrate the proposed method.

2. PSS module division principle

Based on functional requirements, PSS modularization is generally performed according to the following division principles. All these principles are effective in the process of preliminary establishment of product and service components, functional requirements identification and cluster, and final PSS module division.

(1) The independent principle of product and service characteristics: the characteristics of products and services are strived to typical and independent. All the main product and service component/modules are as far as possible independent according to functional requirements. So it is easy to assemble to form a variety of PSS concepts.

(2) The function correlation principle of products and services: all the products and service for achieving the same function are as far as possible to cluster together. Its aim is to keep the independence and integrity of one function, where the connections between products and services modules are least, and the internal connections among the modules are closer.

(3) The category correlation principle of products and services: the products and services have the same or similar characteristics. The related products and services with same/similar characteristics/attributes are divided into the same cluster to form a product service module. This can facilitate for product structure and service activity management. As the same time, the mechanism can provide the customers with more diverse products and services of low costs and high quality.

(4) The process correlation principle of products and services: the product components and service activities have continuity in time or service process. As is, products and services during a continuous process are to achieve the same functional goals within a continuous period of time. All these products and services should be as far as possible to divide into on module.

(5) The structural similarity principle of products: the product should try to make the independent components or the large base pieces as a modular unit considering their independence and assembly ability. Modularization of complex components can enhance the efficiency and flexibility product maintenance and replacement, which reduces the cost and time of product maintenance and replacement.

3. PSS modularization using functional requirement

3.1. PSS and functional requirements analysis

The customers and design engineers can easily identify functional requirements, and preliminary PSS components/modules can be divided by the above principles. The PSS modularization framework is given in Fig. 1 based on identifying the relationships between products and services with functional requirements.

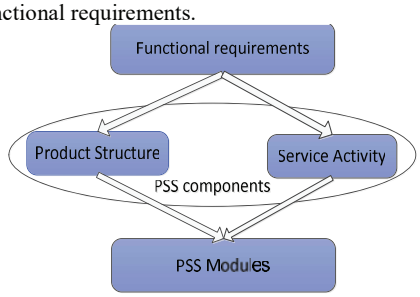

Fig. 1. PSS modularization using Functional requirements

The correlation with its intensity between each two functional requirements can be expressed as shown in Table 1. All the correlation intensity can be used to characterize the relationships among functional requirements.

Table 1. Correlation intensity

Description	Correlation intensity
No or negligible correlation	0
Weak correlation	1
Existing correlation	5
Strong correlation	9

Correlation intensity matrix of functional requirements can be established based on their correlation identification.

Element d_{ij} expresses the correlation intensity between the ith and jth functional requirements, which can form the correlation intensity matrix M in Formula (1), the formula of d_{ij} is shown in Formula (2). When i = j, d_{ij}=1, and $d_{ij} = d_{ji}$, where the matrix is symmetric.