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Product Requirement Modeling and Optimization Method based on Product Configuration Design

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Abstract

Product requirement modeling is a process that the product requirement information is collected, analyzed, structured and converted to the design specification, it is the determinant of the ability to quickly respond to the diverse requirements of customers. This paper presents a product requirement modeling method based on configuration design, which uses "tabular layouts of article characteristics" (SML) technology to conduct the formal expression of product requirement information element. The function structure model and its optimization algorithm are proposed. Enterprises can use the model to interact with customers about requirements and obtain the model which can be manufactured. The customer individual requirements can be satisfied according to the mapping rules of models. Finally, an example of enterprise application is given to illustrate practical application of the research.

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Keywords: Product requirement modeling; Configuration design; Function structure model; Customer requirement

1. Introduction

As the development of computer technology and the increasing fierce in market competition, customer requirements are becoming more and more diverse and personalized. The enterprises gradually focus competition on how to increase external variety of products to meet customers' individual requirements under time and cost constraints by decreasing the internal variety of products, thus realize the maximization of enterprise profit. It also forces the production mode transform from the original mass production methods to mass customization mode. However, the difference of semantics and terminology makes it difficult to map the product requirement information from customers to enterprises designers in mass customization mode, as they expressing product requirement information based on different area knowledge. While product requirement information is short of clear architecture, the relationships between different variables of product architecture are difficult to express formally, so do the relationships between product requirements variables and design parameters [1]. How to obtain the customers' individual requirements through requirements interaction and produce customized products under the current production conditions and cost constraints has become a bottleneck problem which needs to be solved.

Literature [2] proposes an ontology-based requirements elicitation method from the perspective of software implementation. This method makes enterprise ontology and domain ontology as the basic clues of requirements elicitation, Literature [3] adopts the product requirements topology to conduct the acquisition and expansion of requirement information for product life cycle. As a result the systematization and efficiency of requirements acquisition is improved. Literature [4] has a discussion on how to integrate requirement information acquired in the product design process to ensure the consistency of requirement information from the perspective of product design. Literature [5] proposes the customer requirements of coach products on knowledge

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representation and construction methods based on ontology. The customer requirements utility data model and a two-step conversion method is proposed. Literature [6] discusses some of the misconceptions that exist in industries regarding requirements engineering and how user needs typically slip through the cracks under the name of "nonfunctional requirements". Literature [7] analyzed requirement design and its function in concurrent design. Then the method for the market's information acquisition and handling was discussed. As a result, the function of the product was refined. The modeling methods above all assume that the product development and design start from scratch. In fact, however, during the product configuration design process of mass customization, manufacturing model of configurable products are usually designed by mapping historical data through product configuration design and parametric variant design based on the designers' interaction with the customers' requirements. This paper presents a product requirement modeling method of configuration design, which uses SML technology to conduct the formal expression of product requirement information element. It proposes the product FS model and its optimization algorithm on the basis of above. Enterprises can use the model to interact with customers about requirements and obtain the model which can be manufactured and meet customers' individual requirements gradually according to the mapping rules of models.

2. Definition of product requirement information element based on SML technology

SML refers to the characterization of properties of products (including parts, components), such as geometry, features, supplements, algorithms, classifications and properties, and the form of fixed-format tables reflecting the information collection of objects. It defines the decisive characteristic of an object through a way that can be characterized and distinguished from the object group and also the representation format of characteristic data. Description of the products, components and parts through these characteristics makes it easy for characteristic data of products to communicate between different systems. In the production mode of mass customization, basing on requirements analysis and forecasting of future requirements and aiming at a certain customer base to use a series of SML to describe the connection among appearance, function and structure size of configurable products. Furthermore, through SML instantiated, manufacturing models are derived to meet customer's individual requirements according to the configuration rules.

Product requirement information element of configuration design-oriented refers to using SML technology to express the basic unit of product requirements constituting the target feature items, which provides a basic method for acquirement, description, management and use of product requirement information in requirement modeling process. The formal expression of product requirement information element of configuration design-oriented is using SML technology to express the basic unit of product requirements constituting the target feature items, as shown in formula (1):

$$T\_Meta = \{T\_id, T\_datatype, T\_conts, T\_domains, T\_Metatype\} \quad (1)$$

Where *T_Meta* is product requirement information element; *T_id* is a unique identification of product requirement information element. There are two types of configurable product requirement information element. One is associated with geometry, materials, functions, such as color, texture, etc. and the other is related to object structure and assembly relations. *T_datatype* is the attribute value type of product requirement information element, such as integers, real numbers, character, boolean, etc; *T_conts* is the value constraint of the attribute value of product requirement information element. Among it, option means not choosing or selecting a value from the range, and the compulsory is to enter a value or select a value within an interval range; *T_domains* is the range of attribute value of product requirement information element.

3. Configuration-oriented design of Product Function and Structure Model(PFSM)

Configuration-oriented design of product function and structure model (PFSM) are based on formalized express of product requirement information element of SML technology, adjusting attribute value of requirement information element and constraints to meet customers' requirements for personalized expression of functional structure model. Nodes in all levels of PFSM are expressed by Function and Structure units. In PFSM, each node, namely Function and Structure units, has the ability to represent multiple instances of components, which can be formally expressed as formula (2):

$$PFSM\_Unit = \{FS\_id, FS\_option, FS\_type, Mult(T\_Meta_i), is\_decomposed\} \quad (2)$$

Where *PFSM_Unit* is FS units of PFSM, *FS_id* is the unique identification of the FS unit, *FS_option* is the selecting characteristic of FS units. When *FS_option* = 1, it means that the FS unit is mandatory unit of configured products. When *FS _option* = 0, it means that the FS unit is optional unit of configured products. All mandatory units are consist of standard configuration of configured product and all the optional units are consist of matching function and optional configuration of configured products. *FS _Type* is the type of FS units. FS units are divided into two categories. One is the standard FS unit (*FS _Type* = 0), which once selected, no other FS unit information is needed to be manufactured and designed, the other is parameterized configuration unit (*FS _Type* = 1), which has some parameters that must be determined after determination of a certain characteristic values of other FS units or in designing process. *Mult (T _meta)* indicates that the property value of the FS units can be described by units of other various SML. *Is _ decomposed* is the property that if the FS units are decomposable, it can be divided into complex FS unit and element FS unit according to the FS unit which can be further decomposed or not. Element FS unit is in the leaf node location and couldn't be decomposed in PFSM. The complex power structure unit refers to *PFSM_Unit* in the middle layers of the hierarchy tree of PFSM. According to functional requirements, it can be