Requirement Acquisition Method of Product Life cycle Based on HLDA Hierarchy Model under the Background of Web Technology

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Abstract. Product requirement is the goal of product development and design activities, which originates from all stages of product life cycle. In the process of acquiring product requirements, there are some problems such as incomplete mining of product requirements and fuzzy structural expression. In view of the above problems, this paper proposes a product life cycle requirements acquisition method based on axiomatic design. Firstly, web technology is applied to collect requirements information, and based on HLDA hierarchy model, the requirements information is classified according to the whole life cycle stages of products; then, the product requirements mining model based on axiomatic design is established to mine the requirements of the whole product life cycle; finally, the product requirements model tree is structured and the product life cycle requirement model is established; This paper takes shield machine segment erector as an example to verify the effectiveness of the proposed product life cycle requirements acquisition method.

Keywords: Product Life Cycle, HLDA Hierarchical Model Theme, Axiomatic Design, Requirement Model

1. Introduction
Market changes from mass production mode to mass customization mode. Satisfying product demand is the basis for enterprises to develop and possess new products. Product demand runs through the product life cycle, embodying customer's description of ideal product in various aspects, and expressing customer's expectations on product function, performance, price, greenness, recoverability, etc. Therefore, accurately and comprehensively grasping product demand is the first problem that enterprises should solve in product development. In order to obtain product demand more conveniently and comprehensively, some scholars apply Web technology to product demand acquisition. For example, Guo Wei and others put forward a method for timely acquisition and analysis of customer information from WAN on the basis of comparative analysis of advantages and disadvantages of decentralized and centralized Web information sources [1]. But Bin et al. established the architecture of demand intelligent acquisition method for heterogeneous customers by acquiring...
customer needs online, and finally formalized expert domain knowledge to output accurate customer demand information [2]. In order to improve the accuracy of demand acquisition, Ji Xue and others put forward an online comment mining and demand acquisition method considering hierarchical product attributes [3]. Sun Wei and others put forward a prototype system model of online product demand acquisition and processing method based on design warehouse by utilizing knowledge base and product database, customer feedback and maintenance information in online design warehouse [4]. In view of the low reuse rate and fuzziness of product demand information, some scholars put forward an ontology-based demand acquisition method. For example, Wang Chen and others established the existence-expression model of demand based on multi-demand acquisition model to solve the problem of insufficient acquisition and low utilization of demand information, and finally expressed the user needs by ontology [5]. Zhai Lili and others put forward an ontology-based approach to information system demand acquisition in view of such problems as ambiguity of demand acquisition, professional limitations and natural linguistic expression [6].

In the above related literature, scholars, on the one hand, from the perspective of hierarchy and structure of customer needs, construct formal knowledge base, mapping rules and other methods to obtain and analyze customer needs. On the other hand, scholars attempt to solve the ambiguity and uncertainty of product demand by expressing product demand in ontology language from the perspective of ontology. Although the approach mentioned above covers all phases of the product life cycle, it is not described. In order to solve the problems of imperfect demand acquisition and vague expression, this paper proposes a product life cycle demand mining model based on axiomatic design and expresses it by product demand model tree.

2. Collection of Product Requirements

In 1980s, the concept of product life cycle was extended from economic management to engineering for the first time, and the scope of product life cycle was extended from market stage to development stage. The concept of product life cycle from product demand analysis, conceptual design, detailed design, manufacturing, sales, after-sales service, to the whole process of product scrapping and recycling [7].

The hLDA Hierarchical Theme Model [8], proposed by Blei in 2004, is based on the Latent Dirichlet Allocation (LDA) [9], which considers that each document consists of multiple topics and each topic consists of multiple words. Further, by randomly assigning the document vocabulary of the corpus to each topic node, hLDA iterates repeatedly until the topic tree structure and the probability distribution of words corresponding to each topic stabilize, and finally forms the topic hierarchy relationship.

Mining a large number of text comments based on hLDA can understand the main content of user needs: first, hLDA is based on the hypothesis of word bag, and needs subject analysis is realized according to word frequency information. Therefore, by clustering topics and high frequency vocabulary, we can get to know the topics that users generally pay attention to and describe certain product needs. Secondly, the information of tree structure is a derivative and inheritance relationship between parent node and child node, which is similar to the logic structure of comment, i.e. the hierarchical relationship between attribute concepts. Therefore, the structure of product demand-related topics can be analyzed through the hierarchy of demand topic. Based on the above analysis, this paper uses the hLDA method to analyze the whole life cycle of products.

3. Demand Mining for Product Life Cycle Based on Axiomatic Design

From the demand analysis, it can be seen that the demand of product life cycle includes design stage demand, manufacturing stage demand, sales stage demand and after-sale service stage demand. According to the demand classification, the axiomatic design "Z" shape mapping is applied to the deployment of product demand, and the overall demand is decomposed into sub-requirements in different domains.
As shown in Figure 1, after categorizing requirements by product life cycle, product requirements are divided into four stages: Design Requirements (DR), Manufacturing Requirements (MR), Sales Requirements (SR), and After Sales Service Requirements (SSR), one of which usually contains multiple product requirements. In order to further explore product requirements, the concepts of user domain (UD), function domain (FD), structure domain (SD) and process domain (PD) in axiomatic design theory are applied to decompose product requirements. In the process of demand decomposition, there are several situations: 1. One demand needs to be met based on multiple demand satisfaction, such as meeting DR1 demand needs based on FR1 and FR2; 2. Multiple demand needs to be met based on the same demand satisfaction, such as meeting MR1 and SR1 needs to be based on meeting FR3; 3. One demand needs to be met based on meeting one demand. Mining product requirements by mapping method based on axiomatic design above.

4. Product Life Cycle Demand Management Model

Product development covers the product life cycle of product design, manufacturing, sales and after-sales services. Enterprises integrate product demand information through internal questionnaires, communication with customers or web forums. Product information obtained is classified into product requirements at different stages through the HLDA hierarchical subject model. Inter-departmental information collaboration and information integration are carried out through enterprise collaboration platform to realize product demand mining based on axiomatic design; finally, the product life cycle demand management model is established. Intelligent management of demand information in product design, manufacturing, sales, after-sales service and other stages can optimize the demand information management of product life cycle. As shown in Figure 2, this is a demand information management model for the product life cycle.
4.1. Product Life Cycle Demand Sub-model

Based on the demand management model of product life cycle, the demand sub-model of each stage of product life cycle can be obtained by considering the demand classification of different stages. Each demand sub-model is designed according to customer demand objectives and enterprise demand objectives, and each demand sub-model can be divided into smaller size demand sub-models [10].

4.1.1. Product design requirements sub-model. Product Design Requirements Sub-model. The design process in which enterprise needs collaborate with customer needs. Based on the enterprise's own needs, through the analysis of customer demand information, the design objectives such as function target, structure target and safety target are defined to improve the design satisfaction.

4.1.2. Product manufacturing demand sub-model. Enterprise implements the integration of customer production. Enterprise comprehensively considers its own needs while meeting customer needs. For example, based on the process requirements proposed by the enterprise's own department, the enterprise can satisfy the material and assembly requirements proposed by the customers. When customer demand changes, the enterprise will coordinate with customers to adjust the corresponding product manufacturing plan in time.

4.1.3. Product sales demand sub-model. By contacting customers in an all-round way, enterprises can adapt sales strategies to customers' different consumption levels and service needs. At the same time, enterprises need to consider their own cost needs and transportation needs at the sales stage, especially for large and complex products.

4.1.4. Product service requirements sub-model. During the process of using products, customers have the need of enterprises to visit and inspect the products regularly. It is hoped that enterprises can quickly feedback information to their corresponding departments when dealing with and solving after-sales problems of products, and give clear solutions and time. Enterprises expect to improve product performance and competitiveness from recyclability, greenness and other needs.

4.2. Expression of Product Requirement Information

The expression of product requirement information is to express the semantics of customer requirement information in proper form, which can be recognized and processed by computer. The hierarchy of demand objects of enterprises and markets can be divided into product level, component level and part level. The requirements of each level are expressed by corresponding product demand model. Therefore, the description space of product requirements is the formal description of all kinds of attribute requirements related to all levels of products. After extracting and formalizing the product requirement attributes, the characteristic attributes of the requirements in the description space are used as the keyword index. Through mapping with the attributes at all levels of the product, the customer personalized requirements instance is fully expressed in the framework structure. The customer requirement information represented by the framework structure can be matched with the existing requirement framework in the requirement knowledge base. After finding one or several pre selected frameworks that can be matched, it can be recommended to customers as an alternative scheme of preliminary requirements.

5. Application Cases

In order to demonstrate the effectiveness of the product life cycle oriented demand management model method, this paper takes the segment erector of slurry pressure balance shield machine as the research object. Based on the method proposed above, the demand information is mined and analyzed, and the product demand management model is established for example verification.

5.1. Capture and Analyze Requirements.
Through internal questionnaire survey, communication with customers and network forum, the demand data information of segment erector of slurry pressure balance shield machine was collected. Taking conceptual design, manufacturing, sales and service as the themes, the HLDA hierarchical topic model is analyzed. Through the internal questionnaire survey and information collaboration among enterprise departments, the demand information of enterprises in the whole product life cycle can be obtained, such as the process demand information in the product manufacturing stage and the remanufacturing demand information in the service stage. Combined with engineering application and market survey information, the demand themes of conceptual design stage are support demand, mobile demand, rotation demand, promotion demand and grasping demand. In the manufacturing stage, the demand themes are material requirements, process requirements, disassembly requirements and configurable requirements. In the sales phase, the demand themes are durability, ease of manipulation and accuracy. The theme of service phase demand is maintenance demand, recyclable demand and remanufacturing demand.

5.2. Build Requirement Model
In the whole life cycle of products, an information management model with customer requirements as the main line is established to integrate customer requirements and enterprise requirements information for configuration management. In the design process, the requirements can be decomposed according to the composition and structure of the product, and the requirements of a certain level are determined according to the requirements characteristics of the previous level. Sometimes, there are complex interlaced networks between requirements. Each layer of requirements has different degrees of influence on the requirements of the next layer. The final result is shown in Figure 3.

Figure 3. Requirement model tree

6. Conclusion
This paper presents a product life cycle requirement model based on axiomatic design. Firstly, the enterprise demand information and customer demand information are collected by web technology, and the collected requirements are divided into demand topics by using HLDA hierarchical topic model. Secondly, based on the transformation of "Z" shape among demand domain, functional domain, structure domain and process domain in axiomatic design, the product life cycle requirements are mined; finally, the product life cycle requirements classification is established Model. In this paper, the validity of the model is verified by taking the segment erector of slurry pressure balance shield machine as an example. The next step of this paper is to verify the model on the basis of research, analysis and application to ensure the consistency of requirement activities coordination and constraints. At the same time, the application of theoretical research to optimize the demand
information management model, reduce the uncertainty of demand information, and enhance the competitiveness of enterprises.

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