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A user requirement driven framework for collaborative design knowledge management



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ABSTRACT

In today's competitive global marketplace and knowledge-based economy, user requirement becomes an important input information for enterprises to develop new product and a critical factor to drive product collaborative design evolution. Meanwhile, there remains no consensus on how best to support knowledge activities and significant challenges to establishing design information management facing to rapid collaborative product development with dynamic user requirement. This paper introduces solutions for designer to deal with dynamic user requirement information through requirement evaluation and prediction method. In this study, we propose a user requirements-oriented knowledge management concept that is based on a four level hierarchy map model with special regard to knowledge collaboration and information communication. Furthermore, a novel distributed concurrent and interactive user requirement database was constructed, and the framework driven by user requirement was put forward to support collaborative design knowledge management. Finally, the service robot design project of a start-up company is used as a case study to explain the implementation of proposed framework.

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1. Introduction

With the advent of information society and knowledge-based economy, information dissemination and knowledge sharing is becoming more and more important in the process of product development [1]. It is now widely accepted that the effective use of company's knowledge is vital to maintain a sustainable competitive advantage [2]. However, design practices are being applied to an expanding scope of activities which include from digital product interaction of graphic areas, product design, engineer design, product service design, even to business strategy and social policy [3]. User requirement is an important input information for enterprises to develop new product or to improve product design, so an accurate understanding of customer requirement information is the key to provide reliable design decisions for the enterprise design department to optimize their design of resources [4]. User requirement becomes an important factor to drive product design evolution in the service economy era of rapid collaborative product iteration [5].

In today's competitive and expanding global marketplace, competitive advantage lies with those companies that understand and

respond quickly to dynamic user requirements in product development while able to bring the product to the market sooner and guaranteeing the quality, reliability and performance [6]. Meanwhile, as the world increasingly moves towards a knowledge-based economy, so it is particularly important in design and manufacturing environments to build a framework for design development knowledge management to achieve better in all of these aspects which is about the use, reuse, sharing and handling of the design knowledge based on user requirement [7]. There has been a wide range of papers about design knowledge management, such as product design knowledge management based on design structure matrix, design knowledge management with reconstructible structure, or building a design knowledge management system for programmers and so on [8–10]. Yet there remains no consensus on how best to support a designer's knowledge activities and significant challenges to establishing design information management facing to rapid collaborative product development and dynamic user requirement. Furthermore there has been little research on the interaction of users, deciders, designers, and engineers with collaborative design systems concerning to user requirement information [11].

With the rapid development of artificial intelligence and interactive technology, robots are gradually integrated into people's real life in these years. Unlike industrial robots, service robots are closely connected to people's lives because of their special

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service functions. At present, the research on the service robot product is mainly focused on the functional and technical level, without fully consider the user experience, usability of human-robot interaction and real user requirements.

The focus of this paper is to develop a suitable knowledge management framework for collaborative design driven by user requirement to actively respond to the dynamic user situation and diverse user experience (UX) [12,13]. Specifically this paper presents knowledge use, knowledge sharing, knowledge reuse and knowledge handling between users, deciders, designers, and engineers in product design evolution [14]. This paper discusses the utilization of user requirement information and design knowledge in product development and explores empirically how designers seek user requirement information to ensure the framework is developed to support collaborative design knowledge management. Furthermore, the companies can use the framework to interact with designers and engineers and make the right decision about user requirements and obtain the suitable model which can be manufactured and meet customers' dynamic requirements accordingly [14,15].

This paper is organized into seven sections. Section 2 briefly provides a summary research background of design knowledge management and user requirement in the field of advanced manufacturing environment. Section 3 presents the characteristics and levels of user requirement and solution for designer to obtain user requirement information. In Section 4 provides the process of information transformation in product design and introduces the concept of user requirement matrix to achieve acquisition and selection of requirement information in design knowledge management system. Then Section 5 proposes the design knowledge hierarchy mapping model and user requirement-driven framework to support collaborative design knowledge management. Section 6 is a case application of mentioned framework and method. Finally, conclusions and future works are introduced.

2. Research background

2.1. Design knowledge management

Knowledge management (KM) has gained popularity in recent years. Grant [16] states that the KM field has been around for about two decades, and it is not only a critical element of the innovations needed to be successful, but a major "innovation" of itself. Researchers and practitioners have developed theories, models and frameworks that explain KM phenomena and used KM to solve different kinds of practical engineering or management problems [5,7,10,17,18]. Manufacturing enterprises are under increasing pressure to respond to the changing technological revolution and diverse user requirements, which also bring more challenges for designer to create products that meet these requirements [19–21]. Meanwhile, finding relevant design knowledge can be difficult and time-consuming, so knowledge reuse allows more time for innovation. From the view of knowledge, the industrial design is a kind of typical "knowledge innovation" activity [16,22].

As we know, design knowledge management (DKM) is derived from KM and has developed into a new research direction for researchers from information, engineering and design field. DKM involves not merely the design, production and manufacturing process, but throughout the whole process from idea generation to the whole product life cycle of new product development. Improving the industrial design knowledge management is one important factor to improve the level of industrial design [18,23,24]. At present, the research teams conducted many fruitful research on the DKM, which mainly focused on the design knowledge ontology, knowledge warehouse, context based design

knowledge management, design structure matrix method and some specific application of certain design knowledge management. Different kinds of theories, models and frameworks were developed to improve the design efficiency in new product development process [3,5,7,10,25–28].

In order to explore the relationship between user and design knowledge, attempts to better understanding the relationship between users and designers in the design process were undertaken. A matching model between user knowledge and design knowledge is established and a method of explicit and implicit design knowledge management based on product appearance cases is developed. Meanwhile, with the rapid development of computer science and information technology, and the popularization of the internet of things, cloud computing and big data etc. the case-based, cloud service-based DKM systems and applications have emerged to deal with industrial knowledge management problems in automotive, aerospace and heavy machinery manufacturing industry [23,29,30].

Most of the aforementioned DKM-based research provides some insight into the knowledge management with the purpose to speed up the design efficiency using different models or frameworks [3,5,7,25–27], however, they fail to expose and explore the real purpose of product design: to meet the user requirements. In other words, DKM is a good tool on managing design knowledge in a complex system, and offers references for designers to get corresponding product design knowledge. DKM, therefore, is an excellent delivery medium of design knowledge as well as an arena for design knowledge searching, matching and reusing. Comprehensive research, however, have not been proposed for integrating user requirement into DKM systems or frameworks and regarding user requirement as critical information to guide design knowledge management. This paper, accordingly, tries to consolidate the DKM based on user requirement to support design practice among a collaborative team.

2.2. User requirement studies

From the overall strategic perspective, updating and adjusting the relevant product to the target in the view of user requirement and product experience, to develop after put into the market to meet customer expectations of products is vital. The fit of user requirement and product function is an important token of customer satisfaction, the higher level the user requirement fit product function, the higher the customer satisfaction of product [19–21,31,32]. To some extent, the user requirement, as an important knowledge, even determines the final product function and design expression and becomes an important power to drive product innovation [19,33]. Meanwhile, the human-centered design principle also calls for more attention to user requirement while considering the user's physiological and psychological constraints and emotional appeals in product.

Understanding user requirements needs insight details in life and specific usage context, while there's a gap and inconsistency between designers and users in design requirement recognition [34]. Meanwhile, user in different market segments proposed diversified requirements in different user clusters. A product contains different kinds of requirements which have different weight. In other words, they are ranked in order but the order is varying with time. Moreover, there are some differences in users' professional degree and daily usage habits, then the user requirements tend to be ambiguous, even some users don't know what they want [35,9,36]. Furthermore, with the emergence of new materials and new technologies applying in different products, user requirements for new product are becoming various, and the changing speed is fast [37]. Such as the HoloLens, a kind of virtual reality glasses developed by Microsoft, bring users new and robust

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