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A framework for design knowledge management and reuse for Product-Service Systems in construction machinery industry

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ABSTRACT

In the global market, heavy construction machinery manufacturers are transforming their business from selling products to providing services based on their products, i.e. transforming to Product-Service Systems (PSS) business model. This business transformation requires manufacturers to learn past design experience not only on the product design, but also on the product usage and maintenance. Effective knowledge and information management systems can help the business to obtain and reuse the past knowledge in new product design. This study aims to develop an integrated knowledge management and reuse framework for Product-Service Systems business in construction machinery industry. The prototype of such a knowledge management and reuse system has been developed and initially validated. The research shows that the developed knowledge management and reuse system can effectively help Product-Service Systems design for construction machinery.

1. Introduction

Manufactures are continuously pressed to increase their revenues and profitability [1], one way of doing this is to adopt Product-Service Systems (PSS) concept in their business. PSS concept was proposed to promote a focus shift from selling just products to selling functions through a mix of products and services while fulfilling the same consumer demands with less environmental impact [2,3]. In PSS concept, service is incorporated into the design space, which has been traditionally dominated by physical products previously, the PSS can be classified as product oriented PSS, use oriented PSS, and result oriented PSS as can be seen in Fig. 1 [3]. When providing a function instead of a product in PSS business, the manufacturers need increasing their knowledge about how its products perform during use. This means that manufactures have greater scope and motivation to learn from experience of its products in usage-maintenance to improve their core design and engineering capabilities.

The knowledge in product services allows the manufacturer to improve its products accordingly, for example, it could help to reduce the needs for service throughout the product usage phase, and discover latent design errors associated with the product [1,4]. Proper knowledge management and reuse in PSS can achieve social, economic and environmental benefit by providing better products and services [5–8].

For capital construction machinery industry, PSS business model changes the economic situation, the manufacturer increases long-term profit by putting more expensive products which can be refurbished and reused multiple times. For capital construction machinery manufacturers who migrate to the new business model, manufacturers and users need increasing their knowledge sharing and transfer. This knowledge is more important to reduce operation cost, to get greater efficiency, and to offer better service.

This researched company in this paper has been shifting their business to PSS, which requires designers to consider more issues within the entire product life-cycle. For understanding product life cycle issues, designers within this company need to obtain product life cycle knowledge from similar machineries, such as manufacturing knowledge, sales-marketing knowledge, usage-maintenance knowledge, remanufacturing and recycling knowledge, etc. However due to the large size of the company and geographically distributed operations, designers often cannot access required life cycle knowledge effectively and efficiently. There is a need to develop a tool to facilitate this knowledge management and reuse practice. This research aimed to develop a knowledge management and reuse framework for PSS in construction machinery industry.

2. Context

This session gives the context about knowledge management & reuse with Product Services Systems.

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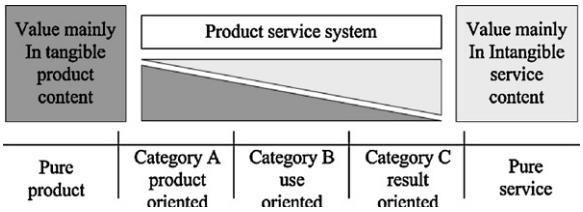

Fig. 1. Placing PSS in a perspective to products and services [3].

2.1. Product design knowledge and knowledge reuse in design

Product development process modeling consists of two interrelated parts: product modeling and process modeling [9]. Product design knowledge includes product knowledge, task knowledge and process knowledge [10]. For a given project, product knowledge is provided through design process interfaces, along with task knowledge (how to carry out the tasks). Process knowledge forms the central element of a design project, it guides designers to carry out their activities in a defined order (which task happens first and which task happens afterwards). The process knowledge also includes links to related tasks and product knowledge sources [10].

In PSS concept, in-service knowledge is important for improving a product design. A significant amount of design knowledge is required during the design process, especially in the concept design phase [11,12]. It is important to capture, represent and reuse design knowledge, manufacturing capability knowledge, and service knowledge in order to support product development in a collaborative enterprise scenario [13].

The use of past experiences and previously acquired knowledge, either from the designer's own experiences or from resources within their organization forms an important part of the design process. It has been estimated that 90% of industrial design activity is based on variant design, while during a redesign activity up to 70% of the information and knowledge is taken from previous solutions [14]. The type of information used changes during the design process [15]. The benefits of reusing design knowledge are provided by fast access to the right knowledge and information, the efficacy of designers will be improved significantly if knowledge generated during the design process is appropriately organized for reuse.

Design knowledge reuse has developed significantly in recent years [16], but it remains a developing area, further effort is required to understand the needs of knowledge users and producers in order that appropriate methods can be applied [17]. Further research is needed to explore the potential of an integrated process and product modeling approach, which should include non-geometric knowledge such as problem solving methods, solution generation strategies, design intent and project knowledge [16].

With dynamically reconfiguring the PSS system throughout its life-cycle, there are more challenges to development knowledge reuse, which is no longer an issue of variant design or redesign. Existing methods to reuse design knowledge are generally not compatible with the whole product design process: most are focused on detail design [16]. CAD and PDM systems can reuse the detailed design knowledge, but the entire life-cycle design knowledge for the early design stage is difficult to obtain, especially usage and maintenance knowledge.

2.2. Product design knowledge and information management through life cycle

In-service knowledge feedback to the engineering designers can be achieved via two different methods, the personalization approach and the codification approach [18]. In companies following a personalization approach, knowledge is closely tied to the person who developed it and is shared mainly through direct person-to-person contacts. Obviously, the personalization approach is difficult to share knowledge for the total life-cycle and multi-domain collaboration, so all companies are placing greater emphasis on the development of information and knowledge management systems as they face greater pressure to get design right first time due to global competition [19]. The codification approach is concerned with making knowledge explicit through its capture and formal representation such that it can be reused. Codification strategies require knowledge gained to be codified into suitable representation, stored and organized such that knowledge may be used at a later stage [20,21]. In practice for PSS, a combination of personalization and codification techniques is necessary and complementary.

3. Preliminary investigations

The researched Company A has always been a leading construction machinery manufacturer and provider in China.

3.1. Products and services practice

The company is formed by a number of branches, which design and manufacture a range of construction machinery products. The company offers customized construction machinery solutions to improve its customer's business efficiency. In order to satisfy its customers throughout entire product life cycle, high demands are placed on the product itself and its functionality, as well as on service and spare parts availability. The company has formed products services networks, where remote monitoring systems are used for monitoring the operation of large products.

3.2. Product development strategy, design tools and methods

Product development strategy in the Company is categorized as standard product development, adaptive product development, and variant product development. The strategy is determined both by the market demand and the available technology capability. Customer requirements are analyzed and captured based on the application scenario of the machinery. Design solutions are developed to meet the customer requirements captured.

There are a series of design systems and design methods in the company. Parametric product modeling method is normally applied to the development of key components. PDM system is adopted in each distributed site of the Company to store all product CAD data, but there is no commonly adopted approach for product design knowledge management and reuse. In addition, there is no tool to support knowledge share and decision making in the design process. There is a need to develop a tool to support knowledge share and reuse in the design process for Construction Machinery.

3.3. Large cranes with the remote monitoring system for PSS

Company A is a supplier of the whole family of truck cranes, terrain cranes, and Crawler Cranes. The cranes are complicated electromechanical systems. The cranes' electrical system and electro-hydraulic control system is very complex, and it is normally difficult in practice for maintenance engineers to analyze the problems and carry out effective maintenance activities. In order to improve the maintenance service, an on-board diagnostics systems and enterprise remote diagnostic center were built to analyze the performance of machinery during its usage.

The remote monitoring technology is a new diagnosis method which integrates computer technology, communications technology and fault diagnosis technology [22]. Fig. 2 shows an example of