Computers & Industrial Engineering 85 (2015) 186–195

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

Modularizing product extension services: An approach based on modified service blueprint and fuzzy graph

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ARTICLE INFO

Article history:
Received 27 December 2014
Accepted 23 March 2015
Available online 30 March 2015

Keywords:
Product-extension service (PES)
Modularization
PES blueprint
Fuzzy graph

ABSTRACT

This study aims at modularizing product-extension service (PES). PES is high-value service solution (e.g., repair, maintenance, and energy management) based on product to help manufacturers to achieve sustainable growth and profitability. Modularization can help to realize customization, increase in flexibility, reusability of service modules, and simplification of complex PES systems, etc. However, compared with tangible product, the modularization of product-extension service has rarely been dealt with, despite its potential benefits. More specifically, the question of how to identify service components and partition modules in the practical context is still an unexplored subject. Thus, this paper proposes a PES modularization approach based on modified service blueprint and fuzzy graph. The PES blueprint is firstly used to represent the whole PES scenario and identify all relevant service components. Then, fuzzy graph theory is utilized to module partition based on correlation analysis results of the service components. Finally, an exemplified modular design of compressor rotor service demonstrates the potential of the proposed method.

1. Introduction

Low value-added manufacturing paradigms of selling only product to users have been unable to meet the requirements of the market and environment. In order to achieve sustainable growth, many manufacturers transit from product manufacturers to providers of service (Geng, Chu, Xue, & Zhang, 2010; Suarez, Cusumano, & Kahl, 2013; Yang, Moore, Pu, & Wong, 2009). They provide high-value service solutions based on product, such as product support, repair, maintenance, energy management, and upgrading and recycling. The service solutions are called product-extension service (PES), which can enhance the utility delivered by manufacturer (Bankole, Roy, Shehab, Cheruvu, & Johns, 2012; Lindahl, Sundin, & Sakao, 2014), and extend the product lifecycle (Amaya, Lelah, & Zwolinski, 2014). Offering product-extension service (PES) also helps manufacturers to be differentiated from their competitors and to be competitive (Johnson & Mena, 2008; Meier, Roy, & Seliger, 2010; Randall, Terwiesch, & Ulrich, 2007). Thus, PES is an important field of business for many industrial companies traditionally manufacturing and selling physical goods. Services benefit their customer with added value and in return increase their turnover and profitability (Koudal, 2006).

Different with conventional products, PES consists of various intangible service processes, activities and service resources, etc. When the external environment (e.g., customer requirements) changes greatly, the manufacturing service providers have to re-arrange service processes and resources, and even to redesign the whole PES to adapt to the changed demands. This may not only lead to increase of the service response time and service delivery time, but cause unnecessary waste of design resources. Modular thinking is a good way to solve this problem, because modularization has been suggested to have many benefits ranging from development to production, such as economies of scale, increased feasibility of change, increased variety, ease of design and testing, decreased lead-times, and easier diagnosis and maintenance (Gershenson, Prasad, & Zhang, 2003; Wang, 2009). Thus, introducing the concept of modularization to PES seems to be a promising approach to cope with the current need for efficient service customization. However, modularity in PES is challenging for designers due to differences between product and PES. The service properties of intangibility and simultaneity make PES impossible to be inventoried (Otto & Wood, 2001). Also there are many stakeholders (e.g., service provider, maintenance engineer, and

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http://dx.doi.org/10.1016/j.cie.2015.03.013
0360-8352/

customer, etc.) involved in service process to achieve functional performance through long-term relationships in a complex value network (Lee, Han, & Park, 2014). Interactions between different types of processes and resources are complex. As a 'dynamic' system wherein various stakeholders This makes the service components difficult to be identified, and it also makes relationships between service components hard to be analyzed. Literature on modularization of physical product does not address specific requirements of PES in terms of its process and resource related character (Seite, Schneider, & Nobs, 2010). Previous studies focus fewer on representation of the whole PES and description of the relationship between service components, which causes difficulty in comprehensive understanding of the solutions and identification of service components. Besides, there are no proper methods to measure and analyze the interdependencies between service components. Most of service modularization researches are qualitative, and they lack specific guidance for PES modularization.

Therefore, to enhance the efficiency and flexibility of PES design, a modularization approach based on PES blueprint and fuzzy graph is proposed. The proposed PES blueprint is used to present the whole PES scenario and identify all the service components. Then, fuzzy graph theory is utilized to achieve service module partition. The proposed method graphically helps the designers to build PES modules. And, to our knowledge, there is no method, or integrated method, in the literature until now.

The remainder of this research is organized as follows: Section 2 deals with the research background of this paper, while Section 3 briefly introduces the main terms of service component and service module, which provide a basis for further methods development of PES modularization. The suggested approach which is based on PES blueprint and fuzzy graph is explained in Section 4. Then, the proposed approach is illustrated with a case study of the rotor service modularization in Section 5. In Section 6, conclusion and suggestions are remarked.

2. Related work

2.1. Service modularization

Sundbo (1994) first introduces the concept of service modularization. Feasibility and potential advantages of service modularization are also analyzed in this research. Advantages of service modularization includes cost reduction, high service quality, service customization, flexibility, reusability, standardization, and simplification (Burr, 2005; de Blok, Luijkx, Meijboom, & Schols, 2010; Rahikka, Ulkuniemi, & Pekkarinen, 2011). Böttcher and Klingner (2011) also propose that service modularization can minimize the problems in service offerings, such as loss of economies of scale caused by no standardization of complex services, less structured planning and provision caused by no ability to handle the service complexity, reinventing or re-planning existing service offerings resulted from no opportunity to reuse existing service offerings, and suboptimal offerings derived from no or poorly documented service catalogues. van Hoek and Weken (1998) note that modularity in logistics services can help to decrease service complexity and achieve better responsiveness in terms of variety. Heckl and Moormann (2009) propose that the modularization technique is a tool for eliminating the intense customer influence and for structuring the service process. Rahikka et al. (2011) believe that services provided in modular form can exert an influence on the value perception of the customer in the professional services field.

Considering the effects of service modularity to company, some researches begin to explore the methods of service modularization. Geum, Kwak, and Park (2012) propose a framework for service modularization by modifying the House of Quality (HoQ) structure with driver-based approach and interrelationship-based approach. Ho, Haung, and Yang (2009) develop a methodology to modularize services of business processes. This methodology breaks process into modules based on the observation that a module can be defined as a group of services having high cohesion and low coupling. Böhmann and Krcmar (2006) discuss modular service architectures theoretically and give an IT industry example. Böttcher and Klingner (2011) provide a method that allows the structuring of service modules for service configuration. Bask, Lipponen, Rajahonka, and Tinnilä (2011) introduce a framework with which different customer service offerings, service production processes, and service production networks can be analyzed in terms of both modularity and customization. Lin and Pekkarinen (2011) propose a framework for logistics service design based on modularity logic and the house of quality. Ma, Wang, and Xu (2011) give the concepts and attributes of a service process system, then put forward the key driving factors of service modularity. A service modularity model is presented including four parts, i.e., service staff, service information, service technology, service entity and equipment. Pekkarinen and Ulkuniemi (2008) aim to explore the literature related to modularity in developing and manufacturing physical products in order to apply the thinking of modularity into the business services context. Based on service process analyzing, Yang and Shan (2009) use a functional relationship matrix to identify relationships between service activities, and then identify modules in services. Kazemi, Rostampour, Azizkandi, Haghighi, and Shams (2011) propose a metric suite to measure the degree of service modularity at the design level from conceptual point of view. The proposed metrics evaluate modularity of a service considering three aspects, i.e., decomposability, composability and understandability. To support the optimal operation of complex machines, Yu, Zhang, and Meier (2008) develop a modularization-based industrial service design and modeling method to realize the customizing service packages. Tuunanen and Cassab (2011) integrate software engineering insights with service process design to propose the concept of service process modularization and examine its influence on customer trial of service innovations. Zhou, Lin, Ma, and Yue (2010) develop a service platform for the IT companies who are service-oriented, and apply a mathematical model to evaluate the degree of modularity of the unique services designed within the modular service platform. Carlborg and Kindström (2014) investigate the role of service modularity in developing and deploying efficient services, while at the same time meeting diverse customer needs. In order to improve the product and service potential, Aurich, Fuchs, and Wagenknecht (2006) give a modular principle to realize the technical product service system, and put forward a process library to design and manufacture module product service system. Wang et al. (2011) deeply investigate the relationship between the physical products and services, and suggest using Quality Function Deployment (QFD) method and portfolio technique to complete module development of product service system.

According to the above studies, all authors contribute valuable aspects to service modularization, but they do so mostly from the conceptual perspective of effects, framework and process. Nevertheless, important aspects related to the key aspects of service modularization remain unaddressed. The important question of how to modularize services in practical terms has rarely been dealt with. The lack of available methodology has meant that the study of service modularization in practical setting has faced the difficulties of working without a systematic approach. In addition, previous studies have generally been pure service-focused, e.g., banking service and IT service (Ordanini & Pasini, 2008; Pekkarinen & Ulkuniemi, 2008), so they may not meet the needs of PES adequately, and appropriate modification is required to