Construct a Customized Product Service System Utilizing Multi-agent System

Cheng-Yen Chang, Chi-Hsuan Tsai, and Ming-Chuan Chu[✉]

National Tsing Hua University,
No. 101, Section 2, Kuang-Fu Road, Hsinchu 30013, Taiwan
fred831226@gmail.com, mcchiu@ie.nthu.edu.tw

Abstract. Over the years, the way customers measure value has changed drastically. If companies still focusing on pure product quality or cost, will gradually lose competitiveness. Considered as a solution to the strategy, the product service system combines tangible products, intangible services, and back-end support systems to reduce the risk of uncertainties and meet diverse customer needs. Although there are many studies on product service systems, there are still opportunities of improving design methods that can provide different content in response to changing need. In view of customization, this paper utilizing text analytic technique to capture PSS improving opportunity, and realizing customization with a MAS-based recommend system.

Keywords: Product service system · Multi-agent system
Recommender system · Text analytic

1 Introduction

Over past few decades, the way how customer measure values undergone great changes. Additional service or customer experience are gradually exerting influence on value chain. To address those issues, product service system (PSS), which combined both product and service for improving sustainability and competitiveness, is therefore heavily discussed and considered as an effective solution. However, due to the increased demand for customized products and the changing trends in customer demand, a more flexible and changing environment will have to be considered when designing PSS. By the ability of dealing changing environment, Multi-agent system (MAS) is considered as a tool for realizing customization. Additionally, to obtain the voice of customer in a changing environment immediately and systemically, design requirement is captured from Internet with text mining technique. To sum up, the aim of this study is utilizing text mining technique to uncover customer needs and redesign PSS, then provide customized PSS to user by a MAS-based recommend system. Section 2 is the review of past study on PSS and MAS. The framework of designing customized PSS is showed in Sect. 3, and with a preliminary result in Sect. 4. Finally, conclusion and future work are discussed in Sect. 5.

2   Literature Review

2.1   Product Service System and Configuration Approaches

Goedkoop *et al.* (1999) first defined PSS as "a marketable set of products and services capable of jointly fulfilling a user's needs"." In the last few decades, PSS has attracted much attention from research teams and industries due to its economic and sustainability potential (Tukker 2004), and it performance been proofed by many cases (Vezzoli (2003); Sakao (2009)). Baines *et al.* (2007) collect and summarize the definition of PSS, and emphasis is on the 'sale of use' rather than the 'sale of product'. Tukker (2004) then elaborate it and developed an eight archetypical model. The focus of recent research has been on designing the framework of PSS development, Wang *et al.* (2011) proposed a framework for product-service life cycle management and technologies of development. Amaya (2014) using lifecycle analysis to design for intensified use in PSS. Other research has also discussed what tools could be utilized in PSS design such as Song *et al.* (2015) proposed a method for service modularization through modified service blueprint and fuzzy graph, and Song and Sakao (2017) using TRIZ to identify and resolve services design. In summary, the literature on PSS design shows a variety of approaches. However, most of precious researches on PSS design are focusing on satisfying customer in general, without the consideration of customization. This study focused on this gap by providing a recommendation system for PSS customization.

2.2   Multi-agent System

Durfee and Lesser (1989) initially defined MAS as follow, "a loosely coupled network of problem solvers that interact to solve problems that are beyond the individual capabilities or knowledge of each problem solver". These problem solvers also named as agents, and each of them can be seen as a separate computer system or software. While each agent is designed to follow their own rule, they can also communicate, coordinate, and negotiate with others to reach agreement. Through interaction, MAS can process and integrate heterogeneous data sources and provide users with a consistent operating environment, which raise the efficiency and flexibility of problem solving.

From the emergence of MAS, it has been applied to many fields. Sun *et al.* (2001) introduced a distributed multi-agent environment for product design and manufacturing planning. Mishra *et al.* (2001) proposed a multi-agent framework for reverse logistics planning. Tsai and Chiu (2017) utilizing MAS and pervasive computing to construct a personalized PSS recommender system. Previous studies indicate that MAS has it potential to solve complex and dynamic problems. Many studies have applied MAS to construct a recommendation system. Nonetheless, few research focused on its potential for solving PSS customization problem, and how can it help in PSS improvement process.

3 Methodology

The framework of customized PSS design process consists of 3 parts and can be further segmented to 5 steps as shown in Fig. 1. Detailed instruction is discussed in following paragraph.
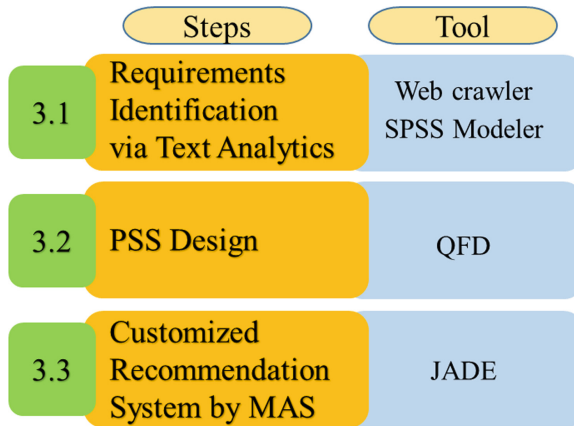

Fig. 1. Customized PSS design process

3.1 Requirements Identification

The beginning of designing customized PSS is to identify what's the customers' requirement. In recent days, customers are willing to share their experience on Internet, these kind of information has advantages of truthful, direct, unconcealed and easy to obtained, all the advantages of it leading Internet data a great potential to capture customer requirement instantly and easily.

With the help of developed web crawler software, decision makers are allowed to capture lots of information from Internet. However, the data captured from Internet are practically long, unclassified and segmented, and thus it need to be further analyzed for better understanding.

Text analytic technique is then utilized to decompose the long and segmented data obtained from step 1. For the purpose of discovering customers' requirements and what present PSS offered do they still unsatisfied, text analytic technique focus on extracting some satisfaction parameters such as good, excellent, bad, not perfect, unacceptable, etc. The result of analytics categorized the obtained data into two prospects - new service we need to developed and present service we need to improve.

3.2 PSS Design

After text analytic, the requirements of customers are clear and prepared for decision makers to design improved PSS accordingly. The concept of designing a customized

PSS is figuring out the potential service or solutions that can be offered to satisfy various customer, and finding the tradeoff between customer and PSS provider simultaneously. There are multiple techniques can be utilized in designing PSS as we reviewed in Sect. 2, including QFD, service blueprint, lifecycle assessment and so on. In this study, we simply utilized a requirement-solution matrix to demonstrate the PSS design process. It's only a simple demonstrate and can be further improved by decision makers.

3.3   Customized Recommend System

After the solution set was established, customized PSS recommend system needs to provide the best fit PSS solution for each customer with various requirement accordingly. With the aim of offering customized PSS precisely, recommend system requires certain parameters (age, gender, weather, schedule, etc.) design for better characterizing each individual.

Multi-agent system consists of different kind of agents, each agent follows their own rule and has the ability of communicating with others to search trade-off. The function of agents is varying, such as sensing and acquiring data, computing, comparing, etc. The framework and simple demonstration is shown in Fig. 2.
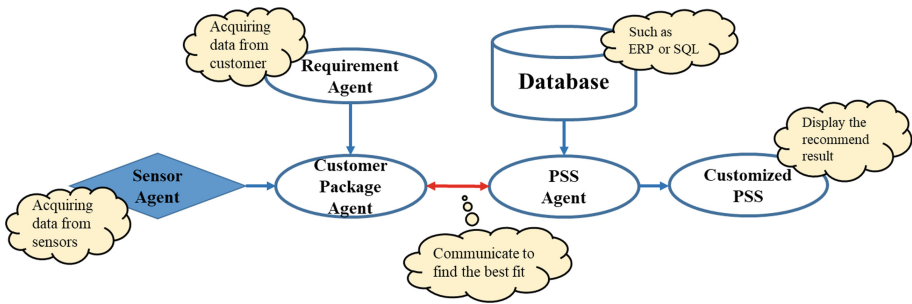

Fig. 2. MAS framework for recommend system

As decision variables stored in customer package agent, specific requirements information of each individual are obtained from either sensor (weather, schedule on smartphone, location, etc.) or customers (preference, gender, etc.). Then, PSS agent obtained product, service, system design data from the database. By communicating with customer package agent, PSS agent is allowed to calculate the best fit PSS solution for individual.

4   Preliminary Results

In this study, we conduct the PSS of bike rental business as a demonstration of the customized PSS recommend system designing process. With a survey into customers' comment on Internet, we discovered there's a gap between customer's expectation and

poor performance of present PSS. The PSS redesign process of 5 steps discussed in Sect. 3, detailed demonstration is showed below.

4.1 Requirements Identification

We utilized WebHarvy software as a text mining tool to captured customers' review on bike rental system. We have totally mined 267 reviews in total from several websites. However, the initial mining results are prolix and unclassified for text analytic. To address this problem, the original data has been treated from 267 review to 2711 sentences. As our goal is to bridge the gap of customer's expectation, text analytics focus on the customers' satisfaction on present bike rental PSS. This study utilized SPSS Modeler as text analytic tool. The process and result is showed below (Fig. 3).
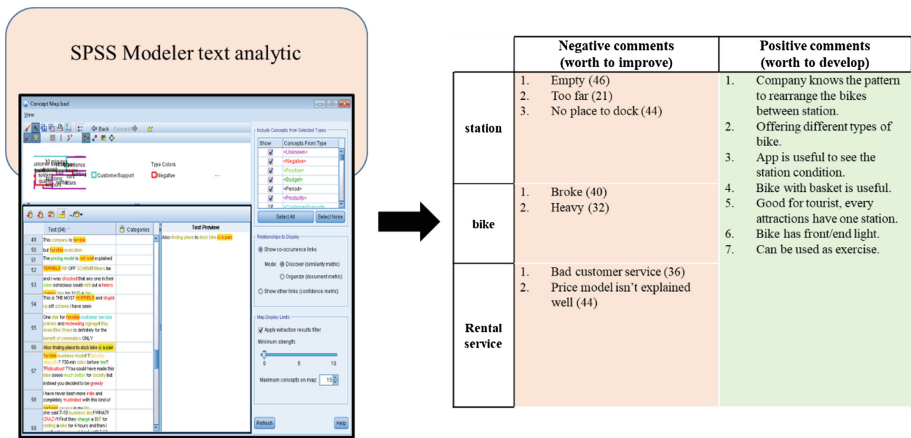

**Fig. 3.** Text analytic process and result

4.2 PSS Design

For the goal is to establish a customized PSS recommend system with service design and MAS as solution, some assumptions have to be made. First, PSS design must have relation to the recommend system. Second, from the result of text analytics, the observation is that we have to design new service for negative comments, while the service demand of positive comments is pretty straight forward. Third, the feasibility of product/service design in following section are proved since some of companies are already providing. A simple evaluation of which function of MAS can dealt with customers' requirement is showed in Table 1 below.

Table 1. Requirement-function matrix

	Customer requirement	Product design	Service design	MAS sensors function	MAS recommend function
Worth to improve	Station is empty			V	
	Station is too far	V			
	Station has no place to dock			V	
	Bike is broken		V	V	V
	Bike is heavy	V			
	Bad customer service		V		
	Price model isn't explained well				V
	Knows the pattern to rearrange the bikes between station		V	V	
Worth to develop	Offering different types of bike.	V			V
	App is useful to see the station condition		V	V	V
	Bike with basket is useful	V			V
	Every attractions have one station	V			
	Bike has front/end light	V			V
	Can be used as exercise	V	V		V

4.3 Customized Recommend System

MAS design start with developing relative decision parameters in reply of customize for each customer. And through the calculation of agents to output the recommend result. The MAS model is designed as below (Fig. 4).
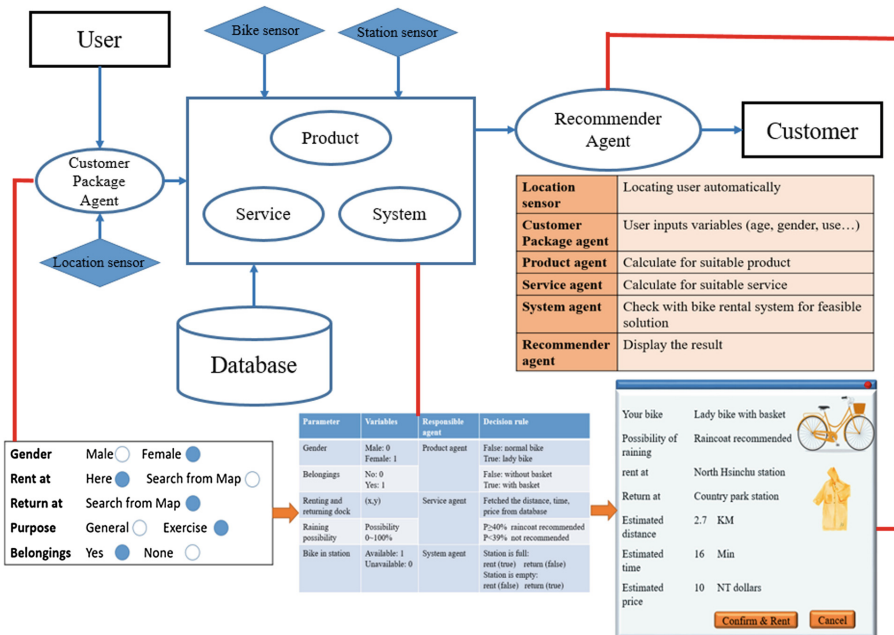
Fig. 4. Customized recommender system structure

While user start using the recommend system, they are asked to choose some parameters such as gender (male or female), purpose (for general transportation or for exercising), location (start and end point). Location parameters particularly can be fetched by location sensors. At the same time, PSS agent also fetched product data (types of bike, basket or not, etc.), service data (price model, nearest dock) and system data (if the dock is empty or full) from sensors and database.

After that, PSS agent follow certain rules assigned by designers to calculate the feasible solution which best fit the user. The rule can be in many forms by correlation coefficient, Boolean (true/false), decision tree, mathematical calculation or simply fetched the result in database. PSS agents will then calculate the recommend solution by their rule after fetched the parameters set by user and the product/service/system data from database.

4.4   Discussion

The whole process is within the goal of improving the performance of present PSS and providing customer a customized solution at the same time. First, compared to traditional way (questionnaire, phone survey, etc.), applying text mining techniques on requirement identification is a systematic and quick way to know the real voice of customers. However, this method only suitable when customer review data on Internet is sufficient and thus has it limitation.

Second, PSS design and customized recommend system design are altogether fulfilling what customer desired. Yet such design is very delicate due to PSS design in one hand has to fulfill customers' need, and have connection with MAS design in another. Additionally, the customize recommend function should be built on the foundation of which PSS is well-developed. To address this issue, the relation between PSS and decision rule of MAS must be processed simultaneously. In this case study, customized recommend system operates well is based on the fact that product, service and system of bike rental system is already developed and proved. But in other scenario, PSS design and improvement should be executed before customization.

5   Conclusion

For the way of customer define value has changed and the demanding of customization has risen, customized PSS is proved to be a competitive solution addressing for the problem. This study integrated several techniques to develop a customized PSS design framework with MAS-based recommend system. First, we utilizing text mining and analytic technique to capture the voice of customer. Based on the result, decision makers could improve and redesign the present PSS model. Finally, the MAS-based recommend system helps to realize the demand of customization.

The contribution of this paper is we suggesting a systematic and simple way of realizing customized PSS. Compared to other PSS design framework, utilizing Internet crawler and text analytic techniques could reduce lots of resource and effort, so as the MAS-based customized recommend system.

However, this study still has several limitations. First, the performance of recommend system haven't been measured in the study. Second, customized recommend system only works when PSS is well-developed. Third, the study (including MAS) is only a demonstration, and need to be improve with a real case and a well-developed recommend system. All limitation above can also be a direction for further study.

References

Amaya, J., Lelah, A., Zwolinski, P.: Design for intensified use in product–service systems using life-cycle analysis. J. Eng. Des. **25**(7–9), 280–302 (2014)

Baines, T.S., et al.: State-of-the-art in product-service systems. Proc. Inst. Mech. Eng. Part B: J. Eng. Manuf. **221**(10), 1453–1552 (2007)

Durfee, E.H., Lesser, V.R.: Negotiating task decomposition and allocation using partial global planning. Distrib. Artif. Intell. **2**(1), 229–244 (1989)

Goedkoop, M.J., Van Halen, C.J., Te Riele, H.R., Rommens, P.J.: Product service systems, ecological and economic basics. Report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ), vol. 36, no. 1, pp. 1–122 (1999)

Manzini, E., Vezzoli, C.: A strategic design approach to develop sustainable product service systems: examples taken from the 'environmentally friendly innovation' Italian prize. J. Clean. Prod. **11**(8), 851–857 (2003)

Mishra, N., Kumar, V., Chan, F.T.: A multi-agent architecture for reverse logistics in a green supply chain. Int. J. Prod. Res. **50**(9), 2396–2406 (2001)

Sakao, T., Sandström, G.Ö., Matzen, D.: Framing research for service orientation of manufacturers through PSS approaches. J. Manuf. Technol. Manag. **20**(5), 754–778 (2009)

Song, W., Sakao, T.: A customization-oriented framework for design of sustainable product/service system. J. Clean. Prod. **140**(3), 1672–1685 (2017)

Song, W., Wu, Z., Li, X., Xu, Z.: Modularizing product extension services: an approach based on modified service blueprint and fuzzy graph. Comput. Ind. Eng. **85**, 186–195 (2015)

Sun, J., Zhang, Y.F., Nee, A.Y.C.: A distributed multi-agent environment for product design and manufacturing planning. Int. J. Prod. Res. **39**(4), 625–645 (2001)

Tsai, C.S., Chiu, M.C.: Design of personalized product service system utilizing multi-agent system. Transdiscipl. Eng.: A Parad. Shift, 845 (2017)

Tukker, A.: Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. Bus. Strategy Environ. **13**(4), 246–260 (2004)

Wang, P.P., Ming, X.G., Li, D., Kong, F.B., Wang, L., Wu, Z.Y.: Status review and research strategies on product-service systems. Int. J. Prod. Res. **49**(22), 6863–6883 (2011)