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Cloud-based approach for smart product personalization

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Abstract

The advancement of information communication technologies (ICT) has begun to change both industrial and consumer products towards ones with attributes of smartness and servitization. Nevertheless, smart features and deep integration with smart environment tend to complicate the effort for the provision of personalized products. To solve this problem, this paper puts forward a Smart Service Products (SSP) model comprising smart environment-enabled features and services-enabled smartness, apart from its own physical capability and functionality. A cloud-based framework for SSP personalization is proposed to enable the supply of personalized SSP with short lead-time and mass efficiency. Hence, a real case is implemented to validate the approach.

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Keywords: Information and communication technology, Smart service product; Personalization; Smartness; Servitization

1. Introduction

The advancement of information communication technologies (ICT) has brought substantial smart features to both industrial and consumable products, changing them towards more multidisciplinary, intelligent and networked ones, i.e. smart, connected products (SCP) [1]. One of the classic examples of a smart product in the consumer sector is the smart phone, as well as smart robots in the industrial sector. In addition, service also plays an increasingly important role in manufacturing. Such a trend facilitates service and physical products to be integrated into a single Product Service System (PSS) [2] to offer customers with a comprehensive solution. The combination of smart, connected products and services provides customers with a number of service functionalities. For example, smartphone has some intelligent functions such as navigation, weather forecast, motion tracking, etc. Apart from the tendency towards smartness, another trend in manufacturing business is personalization. On one hand, consumers have never stopped requesting more customizable options for their desired products. On the other hand, manufacturers also want to offer their customers individually tailored products to gain a competitive edge in the global market and improve profitability. To achieve this with the shortest time-to-market, product configuration system (PCS) [3, 4] has been widely adopted in the product customization process.

However, SCP typically operates in a smart environment [5] and interact with other connected smart devices through an Internet-of-Things (IoT)-based connectivity, which makes the personalization of smart product more difficult. In addition, embedded service functionalities will lead to a more complicated personalization interaction process [6]. To cope with these issues, the smart product together with its service is conceptualized as a Smart Service Product (SSP) in this paper, attributing to the development of advanced ICT and the change of customer’s consumption attitudes. In the scenario of SSP, smart and service features interact and influence mutually to fully realize personal demands. However, the existing product configuration solutions only can partially
demonstrate features of customizable smart product, while hardly display its smart environment and rarely address smart service product configuration.

Aiming to fill the gap, this paper proposes a SSP personalization approach based on the concept of Cloud Manufacturing [7], in which the manufacturing cloud and service cloud can provide corresponding production ability and smart service for SSP, respectively. The rest of this paper is organized as follows: Section 2 reviews the related literature; the concept of SSP, and a generic framework for cloud-based Smart Service Product personalized process are described in Section 3; Section 4 presents a case study to implement the proposed approach with some discussions. Finally, Section 5 concludes the main contribution and limitation of this research.

2. Related work

2.1. Smart Products and Smart Environment

Although the term “smart product” is widely used, there is no unified definition. Various kinds of definition have been put forward according to different perspectives. The most commonly used definition stems from Mühhlhäuser [8], who characterize smart product as “a smart product as an entity designed and made for self-organized embedding into different (smart) environments in the course of its lifecycle, providing improved simplicity and openness through improved p2u (product-to-user) and p2p (product-to-product) interaction by means of context-awareness, semantic self-description, proactive behavior, multimodal natural interfaces, AI planning, and machine learning”. Abramovic [9] defines smart products in the context of Industry 4.0, a smart product can be considered as “cyber-physical products/systems which additionally use and integrate Internet-based services in order to perform a required functionality”. In comparison with regular non-smart products, smart products embedded with a bunch of smart features could better meet individual customer requirement. In the meantime, the overload of smart features will affect the user experience of configuration process especially for the customer groups with very little knowledge about the smart product.

Smart Products have to be considered in the context of smart environment. Das and Cook [5] define a smart environment as the one that is able to acquire and apply knowledge about an environment and adapt to its inhabitants in order to improve their experience in the environment. As the same smart product may perform different function when it inhabits various smart environments [8], and customers’ usage scenario may affect their purchase. The connection object could be different in the smart environment, such as p2u connections and p2p connections. Sometimes the connection of smart products in smart environment could be complicated. The communication of the products or the users may be conducted in either an active manner or passive one. Therefore, four different combinations of communication may occur between different objects, such as passive-passive, passive-active, active-passive, and active-active [10]. As a result, the personalization process of smart products is more complex than conventional products. Handling of smart environment should be recognized as a key issue in the design of PCS for smart products.

There is few articles research on the configuration of smart product. To extend traditional PCS’s compatibility with smart products with overloaded features, Lin [11] introduced the concept of adaptable customization degree of freedom to reduce mass confusion and utilizes Virtual Reality (VR) technologies to generate VR model and offer users immersive personalization environment. Techniques that aid the design process of individualized products and organization of their production in the context of realization of the mass customization strategy is presented in [12], which allows a shortened time of development for a new product, and the integration of additive manufacturing and VR techniques are considered.

2.2. Service-oriented Manufacturing

The ability to easily customize products at low cost, short lead-time is an emerging requirement for the manufacturing environment in the future. Product customization is a complex process that involves different stakeholders and need to map between the product providers’ manufacturing capabilities and the specific manufacturing services that are required for the creation of a custom product. Service-oriented Manufacturing (SOM) and Cloud Manufacturing (CMfg) are the new networked manufacturing mode [13,14], which provide users with various types of on-demand manufacturing services according to users’ personalized demands. These new manufacturing modes are based on effective connections and information of manufacturing resources and abilities.

Based on the concept of CMfg and SOM, many scholars have studied product customization. A general architecture of PCS is presented based on CMfg and discussed the configuration reasoning based on cloud-sourced configuration knowledge, to diversify configurable options by introducing proper CMfg services and to fulfill configuration orders through a cloud-based design and manufacturing platform [3]. A cloud service customized PCS is proposed to enable businesses to provide customized product marketing on the Internet to meet consumer demand for customized products [15]. A PCS that uses the concept of “X-as-a-Service” (XaaS) from cloud computing is presented in [16], which supports a bidirectional integration to production systems by manufacturing services and their descriptions. A product delivery system is implemented in paper [17], which is intended to enable the customized production of technologically complex products by dynamically configuring a manufacturing supply chain.

From the literature review, we found that most of past literature focused merely on configuring product itself without considering much about the configuration of product-related service. To survive and thrive in a competitive market, more and more manufacturers are providing their customers with the means to personalize products and services for meeting diversifying customer needs. Therefore, it is a necessity to fill this gap.
3. Cloud-based approach for SSP personalization

With the intensive fierce market competition, manufacturing enterprises are facing the challenges of meeting ever-increasing customer demands in pursing smart, servitization product, which is conceptualized as SSP in this research. Aiming to enable the provision of personalized SSP with short lead-time and mass efficiency, product configuration technologies are utilized to propose a framework of cloud-based SSP personalization process.

3.1. Smart Service Products

The integration of IT-based service has changed the product pattern, which plays an important role in a smart product. It means the scope and concept of product have been expanded. Under this circumstance, it is very difficult to fulfil dynamic customer needs by physical product innovation alone, and various attempts were presented from different views. Considering the multi-disciplinary nature of product, the authors first study the interrelationship and interaction between domains of product, smart environment and service in pairs:

1. Smart environment and product: Products (i.e. mechanical and electrical parts) have become complex systems that combine hardware, sensors, data storage, microprocessors, software, and connectivity in myriad ways, which formed a SCP [1,18]. A typical SCP has three core elements: physical components, smart components and connectivity components [18]. With IoT-enabled smartness, the major features (capabilities) of SCPs include [1]: monitoring (e.g. real-time visibility of the product condition), control (e.g. operator controls a robot from iPad), optimisation (e.g. cutting tool wear prediction) and autonomy (e.g. auto robot vacuum cleaner). The SCP represents the third wave of IT-driven competition, which changes how value is created and the nature of competition.

2. Service and product: Physical product is servitized or integrated with services to form PSS. The concept of PSS is firstly defined as a set of products and services that fulfills customer needs and has a lower environmental impact [19]. In literature [20], PSS concept is regarded as an integrated system of products and services to provide customers with functions and value that they need. Although many researchers have proposed different definitions of PSS, it has generally been considered as product(s) and service(s) combined in a system [20, 21]. The goals of PSS are to enable innovation models aiming to fulfil customer needs and gain revenue from service transactions.

3. Smart environment and service: The data generated by smart products connected to the Internet also brings a new change. Data from the Internet of Things can be analysed, interpreted, correlated and supplemented and then refined into smart data. Such data then becomes the raw material from which innovative, “Smart Services” are created [22]. By using these smart services, manufacturing enterprises can offer innovative, value-added services, and have the potential to improve user experience. In effect, increasingly more companies are transforming themselves from selling products to selling solutions. The smart service not only refers to the pure software application but also refers to the solution that combined with hardware and software. For example, Michelin is designing a new generation of mobility-enabled services targeted at business customers who manage fleets.

These changes mentioned above reveal that product is moving towards smartness and servitization. Therefore, this paper puts forward a SSP model comprising of smart-environment-enabled features and services-enabled smartness apart from its own physical capability and functionality. According to the diagram, the bilateral-overlapping areas indicate SCP, PSS, and Smart Services respectively, and the central area stands for proposed SSP in which the physical product is extended to smart environment domain and service domain (see Fig. 1).

![Fig. 1 The formation of Smart Service Product](image)

To be specific, SSP is defined as a new paradigm that not only combines products with services to provide customers with comprehensive solutions, but also combines product with smart connected network to get real-time information about products’ status, and perceive the product’s surrounding environment through smart services, with the characteristics of smartness. Comparing with SCP and PSS, SSP can offer more comprehensive smart functions to achieve better user experience. Taking a smart car as an illustration, and IoT-enabled sensor network (i.e. GPS, in-vehicle IMU, LIDAR system, etc.) is the foundation of enormous smart features ranging from automated wipers to autonomous cruise control. From the perspective of SCP, deploying the complex sensor network and communicating with smart environment (e.g. facilities like GPS satellites and other smart vehicles) enable functions such as the rain-sensing windshields with automated wipers for improving visibility during inclement weather without driver intervention and vehicle-to-vehicle communication for autonomously avoiding collision. In SSP, by taking service factors into consideration, within Internet of Service (IoS), sensing-as-a-service model [23] can allow the smart car share data captured from in-vehicle sensors with enterprises or other users, or vice versa, via IoT gateway. For instance, by collecting data from customer usage, the vehicle servicing providers can offer proactive maintenance services for their customers. More directly, the service can be a software-based offer as presented in [24], which is a parking assistant as reconfiguration option to a smart car customer. In brief, the smartness lies in SSP has been extended through the synergy of smart environment based on IoT and service environment based on IoS.
In industry practice, Gogoro Smartscooter[25] can be regarded as a SSP. Gogoro scooter has Bluetooth connectivity with smartphone via the Gogoro App reflecting the feature of SCP. The App also push notification like traffic condition to owners which shows the feature of SS. Unlike conventional electrical scooter, the user of Gogoro can subscribe service of battery swapping (i.e. battery-as-a-service) from 474 battery swap stations instead of purchasing a physical one. Benefiting from the Gogoro’s business model which is IoT-based and service-oriented, their customers have ridden nearly 140 million kilometres in total since 2015.

### 3.2. A generic framework for service product personalization

To deal with individual customer needs, customizing SSP is, in essence, the personalization of physical product, smart environment and service environment. From the perspective of product configuration, existing research on PCS mainly focuses on physical-product-based functions without the consideration of service-related features and smart environment. Thus, according to the characteristics of the SSP, this paper not only addresses the product functionality, but also considers the configuration of smartness and on-demand service. As can be seen from Fig.2, a cloud-based framework for personalizing SSP is proposed.

![Fig. 2 Framework for SSP personalization](image)

In the physical space, three main types of stakeholders are involved in the product customization process. Customer refers to those who need the personalized products, which can be classified into normal users with little design knowledge and expert users with design knowledge [26]. Normal users can only select existing configuration options from the PCS, and expert users have the ability to define his/her own personalized attributes beyond the configuration solution scope (i.e. configuration space). Manufacturing enterprises are responsible for providing of manufacturing resources and capability to realize the production of physical product and then arrange the delivery to customers. Smart service providers include third parties who are responsible for the smart service application of the SSP that provide products with add-on value to enhance products’ competitiveness.

From the perspective of cyber space, as illustrated in the framework, manufacturing cloud (i.e. the Service-oriented Manufacturing platform), IoT and IoS provide the technical infrastructure for the personalization of SSP.

1. The Manufacturing Cloud provides the foundation for physically realizing a SSP. In the manufacturing cloud, massive amount of manufacturing resources is virtualized into a resource pool and encapsulated as cloud services to enable the on-demand delivery of services. Virtualization makes it possible to dynamically divide resources into virtual units or flexibly combine them to a logic unit to meet diversified demands, while the functions of those logic units can be encapsulated using SOM paradigm to serve geo-distributed users and to realize manufacturing resource sharing. Therefore, numerous manufacturing cloud services are easily reconfigurable to fulfill personalized manufacturing task, which greatly increase the customization freedom of products.

2. The IoS has the capability to support smartness of the SSP, i.e. Smart Services. Services in cloud are encapsulated into service resources by semantics description language and can be offered and demanded world-wide to realize the sharing of resources over the Internet. The service cloud participates in the product configuration process in two stages: at the design stage and during the usage stage. During the design stage, according to customers’ needs, customers select the appropriate services to achieve product’s service functions during product configuration process. At the use phase, the appropriate services are offered by proactively push or passively pull after perceiving and processing product status information, which aims to prolong the product lifecycle. Customized services offered via PSS can be treated as product reconfiguration as well.

3. The IoT is the enabler of smart connectivity. Such IoT-based smart connection consists of two different types. The first is the connection with other smart products. The low-cost and compact digital storage, sensors and radio modules make it possible to embed a digital memory into it. Such embedding electronics (e.g. RFID reader, wireless chip, Bluetooth adapter, etc.) can interlace a SSP with others to receive the related data and information and execute relevant control orders. For instance, wearable monitoring devices typically work with a smartphone: chest-worn health monitors typically detect your pulse via an electronic signal and send the reading to your connected smartphone by using wireless sensor network. Here, the chest-worn monitoring can be viewed as a part of the smart environment of smartphone. The other is the connection with smart environment, which reflects the smartness feature of the SSP. They are able to perceive and control their surrounding environment by capturing and interpreting ambient conditions and user actions, analyze their observations, anticipate the users’ intention and eventually perform appropriate actions. Taking the RFID-based indoor positioning technology for instance, smartphone is capable of
recognize where the user is and then react accordingly if the user is in a meeting, the smartphone will switch to “do not disturb” mode autonomously.

According to the personalization process illustrated in the Fig. 2, via SSP personalization interface, customers can state their requirements for customizing a SSP which will be converted into function requirements in terms of smart environment, product functionality, and on-demand service. After that, three configurators (i.e. smartness configurator, product configurator and service configurator) get involved to configure smart environment, physical product, and service environment respectively. The personalization of SSP will be addressed in three aspects: a) desired smart features depending on smart environment are achieved by considering configuration constraints stemmed from customers’ usage scenarios, b) the customization of physical product will be fulfilled by requesting manufacturing services from manufacturing cloud, and c) the provision of demanded services is realized through integrating IoS on basis of service configuration results. On the whole, the configuration task of SSP is decomposed as three sub-tasks to address customer needs on differing domains.

4. Case Study

To implement and validate the approach proposed in this paper, a smart respiratory mask is chosen as the case product to illustrate the personalizing SSP through product configuration.

The main reasons of selecting the smart mask as an illustrative example includes: (1) the product can be highly customized based on users’ facial geometric feature and the customization order of physical parts is partly fulfilled by 3D printing service providers, (2) the product possesses smart connectivity with smart phones and other wearable sensing devices like smart bands which are connected with each other and formed as a smart environment, (3) third party companies can provide value-added services for subscription from customers.

To cope with the case product, a prototype system (see Fig 3) is developed in consideration of configuring physical components (appearance and ergonomics features), the smart environment (user’s smart device ecosystem) and the service environment (health data management function from data analytics service providers).

As the screenshot of the prototype system illustrated in the Fig. 3, the personalized configuration process is conducted as follows:

Step 1 (see the area A): Customize smart environment. Customers can select the smartphone type or other smart devices (i.e. chest-worn health monitors), all of which are building blocks of the IoT-based ecosystem.

Step 2 (see the area B): Customize physical product. Customers can determine the appearance of the mask according to his/her preferences (i.e. the color and component types of the mask as shown in the screenshot). In addition, the personalization in respect to ergonomic requirements is demonstrated in the area 1, in which user can upload their 3D facial scanning files to build individually customized nose cushion (a part to secure sealing as well as comfortability for wearing), making the mask fit the face well. As mentioned in the proposed framework, the physical part is produced by sending service order to the manufacturing cloud. In the case study, 3D printing resources are encapsulated as manufacturing services from which customer can choose on basis of their preferred delivery time, budget and quality of service.

Step 3 (see the area C): Customize smart functions and services. By selecting from different sensor unit types, various functions can be achieved (as illustrated in the area 2). Based on the selected sensor unit and specified smart environment by customers, differing smart service types will be provisioned. As indicated in the area 3, the service “cardiopulmonary health diagnosis” requires heart rate monitoring devices (as stated in the area 4) connected in the smart environment. Therefore, the realization of smartness in the case product necessitates in-product smart sensors, the IoT environment, and remote health data analytics service providers.

Through the configuration system for SSP, customers without adequate product knowledge can customize smart functionalities and subscribe services with less confusion. In this case study, value-added services are delivered by the integration with the IoT-based ecosystem. As a matter of fact, more service types are planned to offer their users in future,
such as respirator filter replacement service; Filter vendors can calculate the remaining service life of the respirator filter based on how many times their customers breathe with the mask (from internal sensors) and the air pollution data from meteorological departments (from external sensors). On this basis, the shipment of replaceable filter for their customer will be arranged in an automated manner.

5. Conclusion

To survive and thrive in a competitive market, increasingly more manufacturers are providing their customers with the means to personalize products and services to meet diversified customer needs. This paper presented a new concept of SSP, which not only combines products with services to provide customers with comprehensive customizable options, but also combines products with smart connected network to get the real-time information about products’ status, and perceive the product’s surrounding environment through smart services. The paper described the framework of cloud-based SSP personalization process, which is used to customize the smart environment, physical product, and service environment respectively. The main contributions of this paper are concluded as follows:

(1) The introduction of the smart environment was made directly available to the system as new configuration options and enabled higher degrees of product customization freedom for customers.

(2) The introduction of smart services changed the configuration mode of traditional products and aid the foundation for customers to realize the reconfiguration during the use phase.

(3) The proposed generic framework for implementing the SSP personalization can be applied in different application domains.

This paper preliminarily investigated the cloud-based approach and framework of SSP personalization process. Despite the novelty, the limitation of this research is that the complex smart environment is not considered. In the future research, the configuration of the complicated connection between products (e.g. complex sensor networks) will be involved.

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