A framework for differentiation in composed digital-physical products

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Abstract

Product-Service Systems (PSS) composed of physical products and digital services are emerging as an important new product category. In this paper we suggest that the established metaphor of "layering" is insufficient to capture the diverse ways in which PSS can be differentiated for, and by, consumers. Responding to this issue, we develop a new framework that centres on the distinction between different modes of horizontal product differentiation, including static, dynamic, compository and user-journey differentiation. Using a Design Science Research (DSR) approach, the framework is applied to two case studies of prototype PSS that use augmented reality to connect physical goods to digital services. While at first sight augmented reality would seem to directly embody the traditional notion of layering, the analysis of these case studies confirms the presence of multiple forms of horizontal product differentiation as well as the flexible composition of physical and digital elements. Building on this analysis, we argue that the uncovered aspects of differentiation should be investigated in the management literature and that the existing metaphor of layers should be superseded by a more suitable one.

Introduction

Firms in manufacturing are experiencing pressure to provide additional value through the provision of services as an extension of their tangible product offerings (Baines et al. 2007). The enhancement of products through services, labelled *servitization* (Vandermerve and Rada, 1988), has led to the emergence of the concept of the *Product-Service System (PSS)* in which the conventional functional proposition of a tangible good is bolstered through the provision of an additional service. There are a number of competing definitions aimed at PSS (Smith et al., 2014). In some branches of the literature PSS are defined as a value proposition (Tukker and Tischner, 2006) or as a competitiveness-preserving innovation approach (Manzini and Vezzoli, 2003). Others see PSS more generically as a conceptual tool to create systems and models directed at customers (Bullinger et al., 2003; Mont, 2001). The rationale underlying this literature is that customer value arises through the benefits derived from using the product instead from ownership. This idea is conventional in a sense that consumers are seen to derive utility through the valuable stream of services arising from a good (Waldman, 2003) or through experiences formed (Lipkin, 2015), not from the good *per se*.

One way of delivering added value is through *horizontal product differentiation* - that is by configuring a PSS to serve different customers in different ways. Approaches to such differentiation range from manual customisation to automated personalisation (Arora, 2008). Various technologies have emerged to deliver such differentiation, including additive manufacturing, which enables the customisation of the physical goods element of a PSS, and data-driven algorithms that allow the personalisation of associated digital services. Of particular interest to this paper are technologies that configure PSS by connecting physical goods to digital services. This is becoming increasingly relevant due to the emergence of augmented reality applications in which digital services appear to be directly overlaid on tangible goods, for example when scanned using mobile phones, tablets or head-mounted displays.

The notion of *layering* services on goods underlies much contemporary thinking about PSS. Forming part of the standard repertoire of marketing (Kotler, 1967; Levitt, 1980), the metaphor of layering suggests that the arrangement of digital (or other) services surrounding the base product can be thought of as a neat *stack* with an identifiable order and predetermined relationships. In general terms, layering describes hierarchical arrangements allowing discrete components, functions, systems and processes to interact (Bratton, 2015), for example in smartphones (Gutierrez et al. 2011; Wang et al., 2012; Al-Hadadi et al. 2013) and augmented reality systems (Sanchez-Vives and Slater, 2005; Barsom et al., 2016; Scholz and Smith, 2016). Forming combinations of physical hardware and software, this paper characterises such applications as digital-physical PSS. Such composed systems are also known as *smart products* (Buurman, 1997; Rijsdijk and Hultink, 2009).

This paper develops a new framework recognising that PSS are made up of different functional elements that may be flexibly (re-)combined or changed by both manufacturers and users so as to deliver different types of horizontal product differentiation phenomena. The framework is explored by applying Design Science Research (DSR) approach to investigate factors that lead to horizontal differentiation phenomena as the outcome of intentional design activity in two augmented reality products. This paper thereby provides explanations as to how different types of horizontal product differentiation come about and allows an investigation of the validity of the layered view of PSS, especially with respect to the realism of its strictly hierarchical logic.

As an approach, DSR can be used to form generalised solutions to real world problems, known as *generic designs* (Van Aken, 2016). The purpose of such generic designs lies in their adoption by end-users to solve problems through a process of contextualisation, resulting in specific in-context artefacts or interventions (Denyer et al., 2008). The relationships between product attributes, value propositions and user preferences and experiences are labelled *generative mechanisms*. Knowledge of such mechanisms yields insight into the causal structure inherent to designs (see, for example, Sayer, 2000). As the research product of DSR investigations, generic designs are made accessible in the form of design propositions aimed at particular users or contexts (Van Aken et al., 2016). Rather than using DSR to formulate a generic design for PSS, this paper adopts the DSR methodology to evaluate how specific horizontal product differentiation phenomena have come about.

The following section spells out the framework for digital-physical PSS centred on horizontal product differentiation. The subsequent section applies this framework in a DSR approach to two augmented reality case studies to demonstrate its usefulness in exposing differentiation-related mechanisms and processes. The final section briefly discusses these findings and outlines avenues for future research.

A framework for horizontal product differentiation in for digital-physical PSS

The concept of a digital-physical PSS hinges on the notion that user input or preferences shape it in some way (see, for example, Bratton, 2015). Therefore, such structures can and should be investigated in terms of their possibilities for horizontal product differentiation, occurring when products within a category differ in ways that do not allow statements of relative desirability, for example by ranking them in terms of quality (Murthi and Sarkar, 2003). The consequence of such differentiation is that individuals are able to derive greater utility from products that match their preferences (see, for example, the classic model by Hotelling, 1929).

Traditional attributes along which products can be horizontally differentiated include colour, taste, and shape. Levitt (1980) provides an account of a core product surrounded by additional differentiable aspects, including delivery, contractual terms and support, in a supplier-determined, layered arrangement. Anticipating concerns that user-determined configurations may be important, Andonov (2006) adds a sixth level to the framework by

Levitt (1980), in which the users are given the space to "customise their [products] and use them to their liking" (p.4). To assess such processes, this paper proposes a new set of categories of product differentiation incorporating the following elements: static differentiation, continuous differentiation, compository differentiation, and user-journey differentiation.

Static differentiation within a single functional element

Where the elements of a PSS are statically differentiated, the content of a product or service element is changed either initially or as an instantaneous and discrete change at a specific time. While these changes might amount to changes in the design of functional elements, more limited interventions, such as the changing of settings or parameters, are also considered differentiation activity. Where successful, static differentiation will result in an improvement of the overall performance of the PSS and hence enhance its value to the end-user. Such changes are likely to be made prior to the acquisition of the PSS and include one-time customisation, personalisation, the introduction of different variants, and one-time adaptation to user requirements. Traditional frameworks for describing hybrid product-service offerings concentrate on this type of differentiation; they include complex product systems (CoPS) focused on the supply of financially and knowledge intensive products (Hobday, 1998) and complex product services (CPS), which refers to capital goods with integrated downstream services (Caldwell and Howard, 2011). Specific examples of this type of differentiation include the personalisation of settings in a smartphone, user-specific adjustments within a software package, and customising a maintenance contract bundled with a piece of industrial equipment.

Continuous differentiation within a single functional element

It is also possible that elements of composed products are differentiated on an ongoing basis. Such dynamic changes will improve performance over time and occur in a continuous fashion, constituting a process of product adaptation that does not proceed in discrete steps. Examples for this type of differentiation can be found where use-phase data are collected and fed into product optimisation schemes in a continuous way. Industrial applications featuring this kind of differentiation comprise, for example, aircraft engines, where engine parameters are constantly adjusted subject to user requirements, and industrial machinery featuring reactive maintenance schedules that can be changed on-the-fly. Consumer-facing examples of continuous differentiation can be found in many internet services that generate suggestions on the basis of data continuously collected form the user to make suggestions for online searches or in the common "customers like you bought" function provided by online retailers.

Compository differentiation

This mode of differentiation, which is unique to composed technologies such as digital-physical PSS, reflects changes to overall PSS through the addition or removal of elements, thereby determining what patterns of use are possible within any current configuration. Compository differentiation can occur as a one-off change or in a rolling mode, in which elements of the PSS are periodically added or removed, for example in the form of product or service elements that can be toggled on or off. Changes to the composition of the PSS are likely to be undertaken by both the vendor and the user of the PSS. Setting it apart from the other forms of differentiation described in this paper, compository differentiation entails qualitative changes in a sense that an element can be either 'present' or 'not present' – implying that that gradual, continuous changes to the actual composition of the digital-physical PSS are not possible. Examples for this type of differentiation include the installation of software applications on computers in general, the installation of synchronising functions between different devices and the activation of dormant features within composed systems. A specific example would be the installation of a web-controlled heating system in a residential home.

User-journey differentiation

The final, and perhaps most pertinent, type of differentiation likely to be encountered in digital-physical PSS is user-journey differentiation. Occurring exclusively as an ongoing process during the actual use of the PSS, this mode of differentiation is shaped directly by end-user decisions regarding which element of the PSS is accessed and how, thereby mapping out the actual stream of services delivered by the PSS in real time. This generates highly detailed and complex usage data that can guide future design improvement and consumption patterns. It is possible that the pathway generated during each session splits up into multiple concurrent paths, each accessing a different element of the PSS, with the possibility of re-joining into a single path. Each session will thus generate its own pathway and have a unique character which makes mapping user journeys a challenging task (Quinn et al., 2016). Examples for such ongoing and instantaneous user-determined differentiation are surfing on the web, using an online broker for day trading of financial products, utilising augmented reality functions to perform work or the live remixing of music at public performances.

Case studies

Having introduced digital-physical PSS as differentiation-creating systems, this section analyses two case studies, both of which employ augmented reality to connect digital services to physical objects. Using the DSR methodology, the analyses crystallise out the design propositions of each case study, with special attention on specific usage contexts, design interventions that can occur in the contexts, generative mechanisms that can be triggered, and differentiation outcomes.

The Carolan Guitar

Guitars are examples of high-value products whose value can lie in their personal meaning, associations and provenance as much as in their immediate utility as a musical tool. Vintage guitars with a verifiable pedigree command high prices in the second-hand market while there is also a market for new signature instruments that are endorsed by celebrity players. As a PSS, the Carolan Guitar is an acoustic guitar that employs aesthetic augmented reality markers inlaid into its wooden body that connect to a digital history of how it was made, where it has been, who has played it and how they used it (Benford et al., 2016). As shown in Figure 1, Carolan features six different augmented reality markers located at different points of its structure. An accompanying app allows players to scan these to access multiple digital services including user guides, social media, online videos and the instrument's own blog. The app also allows the user to choose among different mappings, each connecting to an associated bundle of services. Additionally, the app allows the creation and publication of own mappings, for example connecting Carolan to personal websites and media, enabling the instrument to acquire new aspects of digital functionality over its lifetime.

Figure 1: Augmented reality markers inlaid into the Carolan guitar.

Carolan was released 'into the wild' to visit different players. Over the course of one year it stayed in 6 homes, performed at 3 gigs, was used in 2 recording sessions, visited 8 jam sessions, hosted an 'open mic' event, resided in a shop and undertook an international road-trip, during which more than 30 players contributed material to its digital history. Throughout this journey, the users dynamically created and swapped mappings to adapt the instrument to particular contexts, for example selecting a different mapping for learning, performing, recording or showing the instrument to a friend. Over time, the principle of fixing some markers on the guitar to always point at the same information evolved (e.g., the headstock pointing to the maker's certificate and the sound hole pointing to the user guide). Other markers were treated more fluidly, allowing users to point them at their own services and content.

The design proposition underlying the Carolan Guitar can be expressed in terms of the so-called Context-Intervention-Mechanism-Outcome (CIMO) logic. This element of the DSR methodology enables systematic reasoning about the relationships between the contexts in which a product is used, interventions that address these, specific mechanisms through which the interventions take effect and intended outcomes (for more information, see Denyer et al., 2008). Correspondingly, CIMO assumes that a number of contexts *C* exist, in which interventions *I* take place and release certain generative mechanisms *M*, thereby producing outcomes *O,* which are of value to the end-user and classifiable in terms of our framework. Figure 2 summarises the design proposition of the Carolan guitar using CIMO logic.

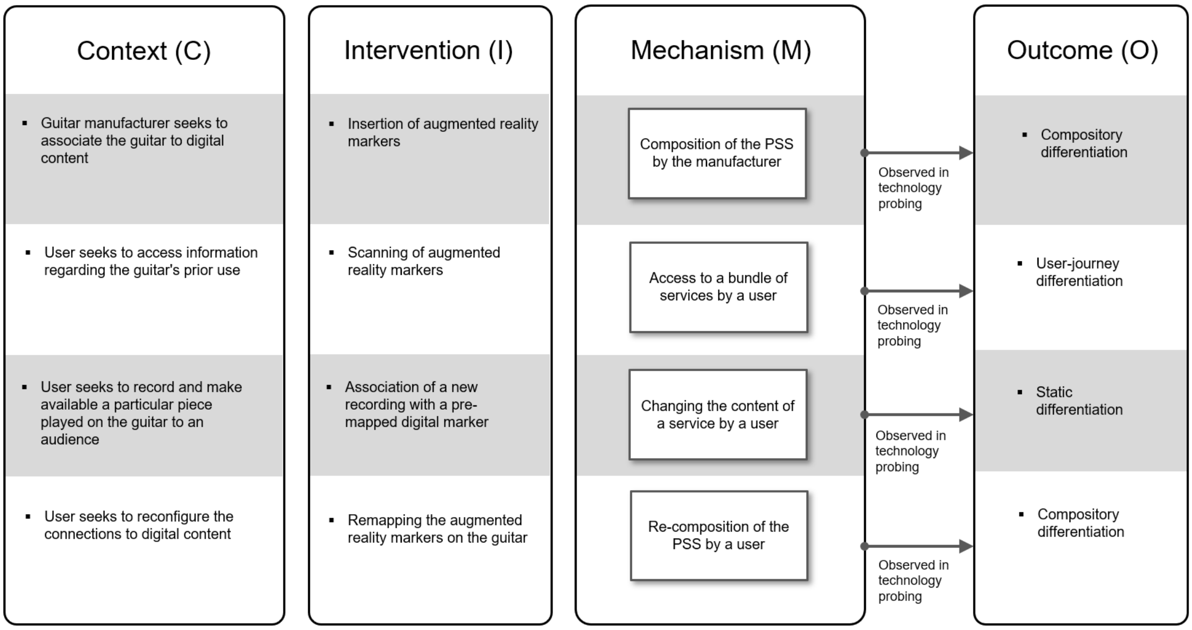

Figure 2: Design proposition of the Carolan guitar in the CIMO logic

Christmas with Artcodes

The second case study brings us closer to the world of mass-produced consumer goods. The Christmas with Artcodes augmented reality advent calendar explores the idea that augmented reality might connect a traditional paper-based calendar with digital services, especially if provided by social media. The advent calendar, shown in Figure 3, is accompanied by 24 stickers that can be placed under its doors, each being a decorative augmented reality marker, similar in function to the ones inlaid into the Carolan guitar. The intention of supplying stickers is to offer a simple entry-level step to customisation while also allowing the calendar to be assembled at a time of its user's choosing.

Figure 3: The Christmas with Artcodes advent calendar opened up

The calendar is supported by an app that delivers digital content whenever a sticker is scanned. By default, the mapping directs the user to a series of Christmas-themed and freely available webpages curated from the internet including links to Christmas songs, animations, classic movie clips, jokes, games, puzzles and suggestions for seasonal cooking and crafting activities. Users are also able to link stickers to own digital content, as shown in Figure 4. The resulting customizations are stored in a local version of the calendar and can be shared with other calendar owners, for example family and friends, as a link embedded into email, text and social media. In turn, incoming mappings received from other people were added to a local list that could be selected from. Users were thus able to create, share and select their own content, providing personalised experiences for others. Finally, blank stickers and instructions were provided to enable calendar owners to learn to design their own bespoke augmented reality markers rather than using the default ones supplied with the product.

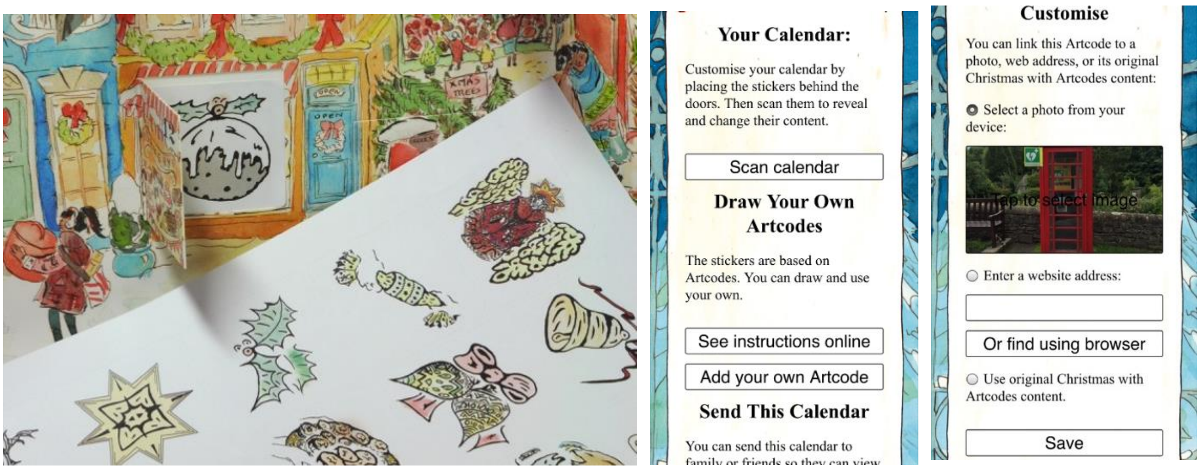

Figure 4: Placing the stickers under to doors (left) and customising the calendar's digital content through the app (middle and right)

Deployment of the calendar began in mid-November 2016 and involved selling it as a product on the Etsy online store (13 sales at a price of just under $20), running workshops for the public at a local craft shop, a local museum, the Mozfest festival, and at a major media organization, and distributing the calendar as a promotional Christmas gift to friends, researchers and sponsors much as one might send a corporate Christmas card. In total 500 calendars were distributed, which painted a broad picture of how and when people interacted with the calendar; a survey questionnaire; and interviews at the workshops (Benford et al., 2018). For many users, the customisable markers enriched the social experience of the calendar connecting to remote family and friends. Others found value in crafting and making, for example with parents and children collaborating together as part of an advent activity. Yet others saw added value in being able to select relevant layers of content.

Figure 5 summarises the Christmas with Artcodes calendar using CIMO logic. As can be seen from the differentiation outcomes, use cases relate mainly to compository differentiation. It should also be noted that the calendar is a product with potentially more than one user since the user configuring the calendar might not be its ultimate recipient.

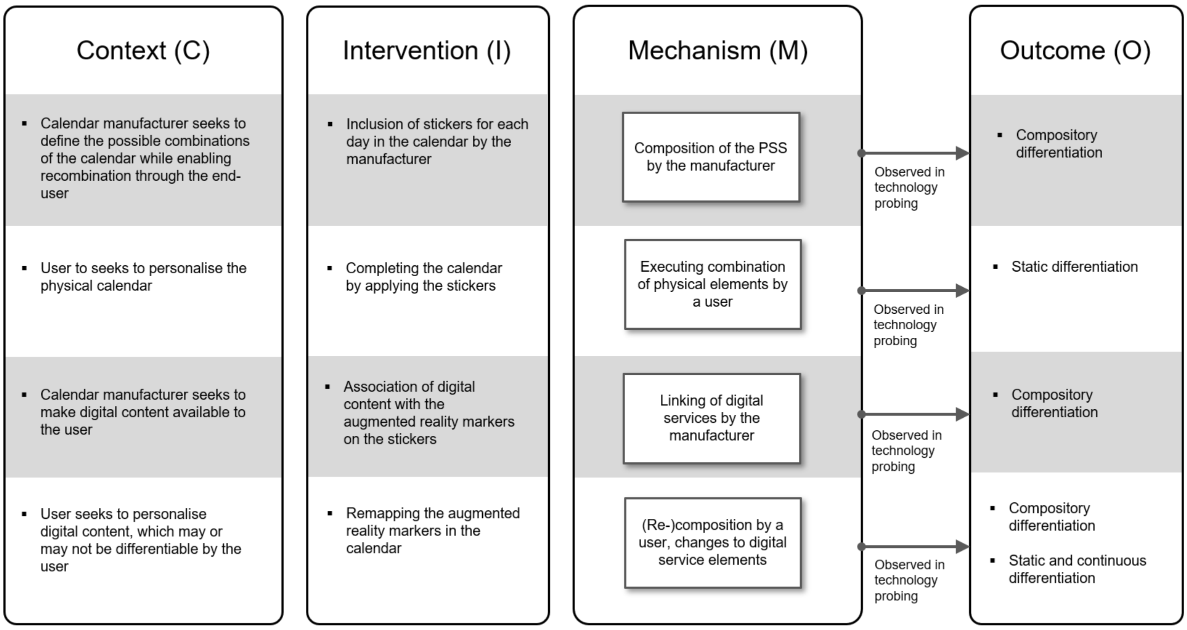

Figure 5: Design proposition of Christmas with Artcodes

Discussion and conclusions

Even at their most basic level, technologies emerge as the result of a recombination of other more fundamental technologies (Arthur, 2009). The view of PSS as a collection of layers (see, for example, Bratton 2015) reflects this composedness and, in a limited way, allows for interchangeability as required for compository differentiation – adding or removing particular functions. Strictly speaking, however, such adaptability requires the overall structure to be non-hierarchical in that individual elements can be removed, and other elements can be inserted, without invalidating the overall structure. In this view it is not always clear which functional element is more fundamental than another – consider, for example, a system consisting of one physical product and multiple digital services, such as in the presented case studies. As the case studies illustrate, various elements of PSS in reality often exist comfortably alongside each other, which is not well-reflected in models of vertical hierarchy such as the layered metaphor. The case studies presented in this paper thus highlight the need for a new conceptual framework that can serve as a more general model for digital-physical PSS.

Focussing on horizontal product differentiation, the case studies reveal the rich ways in which such PSS are differentiated both by the designers and by the users. Moreover, it has been shown that the complexity of the horizontal differentiation of PSS can be systematised meaningfully by adopting a framework featuring distinct modes such as static, continuous, compository and user-journey differentiation.

Two immediate directions for future research can be drawn out from this framework. The first is to further explore the collective aspects of differentiation and how this might contribute to management literatures, in particular those relating to ecosystems (Moore, 1993; Iansiti and Levien, 2004; Jacobides et al., 2016), co-opetition (Bengtsson and Kock, 2000; Luo, 2004) and co-creation (Prahalad and Ramaswamy, 2004). A notable feature of both case studies is how the PSS became embedded into the social world of consumers: in both cases, the augmented reality software allowed users to re-differentiate others' configurations via the mapping of augmented reality markers to services.

The second direction for future research is to look beyond the metaphors of layering and stratification to create a more appropriate metaphor for complex and highly differentiated PSS. Acknowledging that real-life PSS configurations are too messy, transient, and user-determined to be describable along the traditional metaphor of functional layers, a new model based on a different metaphor could be used to reflect the state of rich and untidy composedness encountered in digital-physical PSS. This could be inspired by the philosophy of Peter Sloterdijk (2011), who uses the image of spheres, bubbles and foams to show how relationships bind individuals together to form flexible and mutable agglomerations of constituent elements and functions. Applying from this imagery, bubbles could be used as a term to represent individual objects or services as the building blocks of digital-physical PSS. Unlike the layered metaphor, foams possess transient, fluid boundaries and are marked by irregular compartmentalisation that can be complex and idiosyncratic, resulting in complex patterns of usage and differentiation, as indicated in our case studies.

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