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Publication date
2016

Document Version
Final published version

Published in
Proceedings of ICE/IEEE International Technology Management Conference

2016 International Conference on Engineering, Technology and Innovation / IEEE International Technology Management Conference (ICE/ITMC)

13th to 15th June 2016 - Trondheim, Norway

"Bringing Forward the International Agendas for Entrepreneurship, Innovation, Technology & Engineering Management: Women & STEM Leadership, User-Driven & Frugal Innovations and Tech Startups“

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Towards a Methodology for Selecting Product Usage Information Sources for the (Re-)Design of Product Service Systems

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***Abstract*— A product's value is increasingly determined by the services supporting it. Complex Product-Service Systems (PSS) – combinations of services and products – are in demand. Product usage information (PUI), that is, information about how an individual product is used, is rapidly becoming a valuable asset to industry to help inform service offers throughout the product lifecycle. Conventionally, information about how a product is used is gathered in customer relations and MRO (maintenance, repair and overhaul) processes via channels such as repair logs, call centres or helpdesks. Today, new channels of PUI are emerging from the digitalization of products, the Internet of Things, Cyber-Physical Systems, Internet PUI sources and social media. However, there is a lack of a methodological approach which companies use to select the right PUI source for the design of services, and vice-versa, to understand which value-added services can be offered using information already generated by sensors embedded into their products or available on the Internet or in social media. This contribution is intended to show an avenue of research towards such a methodology.**

Keywords—PSS; product-service systems; PUI; product usage information; product lifecycle management; extended products; ontology; sensors; social media

I. Introduction

Servitization [1] is becoming an increasingly important factor in today's marketplace. Consumers, industrial customers and manufacturers [2] are all driving this trend, which has been noticeable in industry since the late 80´s. It describes a movement away from *"the old and outdated focus on goods or services to integrated "bundles" or systems, as they are sometimes referred to, with services in the lead role"* [1]. Similar, less wide-spread concepts such as hybridisation, tertiarization, service infusion, or servitization refer to similar developments [3]. The resulting integrated combinations of products and services are referred to as a Product-Service System (PSS). Other, related terms refer to specific types of PSS and include product-services (Tukker and Tischner 2006), extended products (Jansson and Thoben 2005), functional products (Lindström et al. 2015), and industrial product service systems (IPS2) (Goedkopp et al. 1999). In the following, the term PSS is used to describe product-service bundles in general. More specific terms are only used when differentiation is appropriate. Servitization is used to describe the process of adding services to a product to create a PSS.

Whilst the informatization and digitalisation of physical products offers companies a wealth of new opportunities to servitize their products on the basis of knowledge about their actual use, there is currently no methodological approach to understanding which services require what PUI feedback loops, and vice-versa.

II. Product Usage Information

A. Conventional Sources of PUI

Product Usage Information, or PUI, is information which is generated when the product is in use. Usage (or, utilisation) is the primary process of the middle-of-life (MOL) of the product lifecycle according to [4]. The same authors also locate service and repair processes in MOL. This is shown in Figure 1, with the MOL and its major processes highlighted. The two latter processes, which encompass customer relationship management during product use and MRO (maintenance, repair and operations or maintenance, repair and overhaul) tasks, have traditionally been the primary sources of PUI for companies. This kind of information is collected, for example, by call centres in the course of customer surveys or MRO technicians in maintenance logs. The information may be stored digitally in CRM or MRO systems but are often collected in databases, spreadsheets, on paper or as recorded telephone calls. Often, companies do not share this kind of PUI beyond the boundaries of the service or MRO processes. This information is often unstructured and qualitative. These factors mean that it is difficult to process automatically, because the interpretation of an expert in the respective knowledge domain is required. Diagnostics logs and operation logs, which are also stored in databases, spreadsheets or log files, are more structured and often offer more qualitative information, which can be more easily processed automatically. However, they generally only give an insight into a very specific interval of product use, and quite often only pertain to a problem with a product. They offer little insight into general patterns of usage behavior.

Figure 1: The Product Lifecycle with MOL highlighted

B. Informatised and Digitalised Products as PUI Sources

Today, additional sources of PUI are becoming available. Increasingly, informatized and digitalized products are capable of measuring, recording and communicating parameters during the utilization of a product. Collecting PUI to obtain particular insights into product use has been long been common in the exploitation of websites and software, as well as hardware such as computers, smartphones and digital cameras [e.g., 5, 6, 7]. Now that the Internet is evolving *"from a network of interconnected computers to a network of interconnected objects"* [8], also referred to as the Internet of Things (IoT), more and more categories of products offer opportunities for collecting data about how they are being used. This trend is extending to product categories that are deployed to achieve mostly physical effects, which did not traditionally produce any processable data. It is facilitated by the fact that product functionality is increasingly realized with the help of information-producing and networked solution elements such as embedded software, sensors – which convert measurements from the physical world to data – and actuators, which convert data to changes in the physical world. Companies can track the movements of these products and monitor interactions with them, which inspires new business models taking advantage of these behavioral data [9].

The process of collecting, storing and analyzing data from customers and end-users of product-services with the goal to discover new needs or identify changes in usage patterns is called informatization by [10]. Informatization is done to enhance existing product-service offers or the related service-level agreements (SLAs) back to the customer. [10] systematize this process as an information feedback loop beginning with collecting and storing data from customers, analyzing it to create data about them, and providing information about new service offerings back to the customer, after which the loop is repeated. As PSS's are seldom provided by an individual company, and the economics of scale in the networked economy stem from the size of the supporting network (Kelly 1999), multiple information feedback loops are opened amongst the stakeholders in the PSS network.

One emerging source of information for these feedback loops is the result of the increasing digitalization of products, services and PSS. According to [11], digitalized products are those, which have seven material properties: programmability, addressability, senseability, memorability, communicability, traceability, and associability. This enables a loose coupling across the four layers of a digital service architecture, which includes devices, networks, services and contents. Other authors have previously developed concepts for "digitalized" products, such as smart or intelligent products. These are physical products which may be transported, processed or used and which comprise the ability to act in an intelligent manner. McFarlane et al. define the Intelligent Product as *"a physical and information based representation of an item [...] which possesses a unique identification, is capable of communicating effectively with its environment, can retain or store data about itself, deploys a language to display its features, production requirements, etc., and is capable of participating in or making decisions relevant to its own destiny."* [12] The degree of intelligence an intelligent product may exhibit varies from simple data processing to complex pro-active behavior [13]. Digitized or intelligent products can thus make use e.g. of RFID, sensors and embedded computing to collect information about their usage, service, maintenance, upgrading, decommissioning and disposal throughout their lifecycles and feed it back to stakeholders responsible for the PSS offer.

Informatization and the digitalization of physical products creates opportunities for companies to create added-value services which make use of the newly accessible, digital information. The added-value services can be tailored to the specific context of the end-user's usage and specific context the core product is employed in. The product extension service can be delivered as software embedded within a product (e.g. a navigation system in a car, or a music service with recommendations in a smartphone). It could also be delivered by more traditional means such as a direct customer contact. An example for this could be a predictive maintenance system in a machine, where the operator is informed of a recommended maintenance procedure by phone or email. These examples have in common that a software system collects information about product usage, processes that information and provides the end-user with an individualized service based on the results of the analysis.

C. Internet-based Sources of PUI

In addition to conventional PUI sources and those which utilize embedded computing resources in digitalized products, more and more information about product utilization can be found on the Internet. Social network services have become a major medium for consumers to express their experiences with and opinions about products. This growing presence of customers on social media can be used by companies to capture PUI about their products. Comments about product use proliferate all of the major social media platforms, and often companies implement their own product page or group for consumers to express their opinions about these products. Dedicated company fora and blogs also serve this purpose. Generally, however, these channels are used for marketing or product and service support purposes and less for the systematic collection of PUI for servitization purposes. Similarly, comments and ratings on e-commerce websites often also carry reviews about product use. In common with much conventional PUI sources, the data generated in these Internet sources is often unstructured and difficult to process without expert interaction.

Innovation processes already make use of social media via "open innovation" [14], where product and service innovation is done by crowdsourcing, so that customers, end users and sometimes also potential competitors are encouraged to engage in an innovation process where they can initiate and support the conceptualization of new innovative PSS.

D. PUI Feedback Loops

In order to deal with global competition, companies are increasing the number of new product introductions in the market leading to decrease the time-to-market and consequently to shorten the life cycle of the product itself. To fulfil this trend and support collaborative new development processes for product-services, unique opportunities are required to create new feedback and feedforward loops to those traditionally 'distant' stages of the lifecycle (see Figure 2).

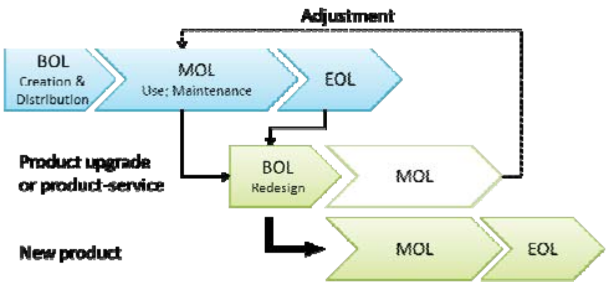

Figure 2: PUI Feedback Loops

This can be achieved by extending the Product Lifecycle Management. Particularly, the MOL phase will be attributed additional characteristics, namely: adjustment for specific users in case of product-service up-grade or redesign of a new product-service, leading to an extension of the lifecycle. This way, a generic product-services lifecycle management scenario can be outlined (see Figure 3).

By incorporating intelligent PUI feedback and feedforward loops, current product development systems (such as PDM/PLM, or CAx tools) and methodologies can be extended to benefit from user experience and product-service usage. On that basis, tools can be designed which provide features that enable awareness and agility in design and provide specific and customized monitoring in a real-time environment. In order to support this functionality tools will need to be coupled with third party software, in order to provide intuitive and established access to product-services development. Particularly, new and innovative features to support faster search will be enabled using semantic technologies in order to support reusable designs and increase reactivity to user's requirements and new demands. This requires a general approach to selecting PUI sources for the (re-)design of PSS and fundamentally, a substantial and comprehensive model of general PSS and specific PSS knowledge domains related to PUI sources and attributes as well as respective product extension services.

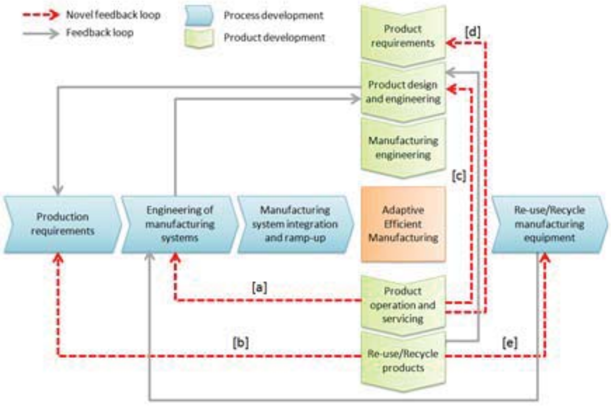

Figure 3: Generic PSS lifecycle management scenario

E. Methodologies for Selecting PUI Sources for the Design of PSS

PSS literature currently makes no mention of general methodologies by which PUI sources can be systematically mapped to product service extensions for use in PSS (re-)design. US patent US 7707060 B2 [15] describes a general PUI feedback loop whereby PUI from autonomic logic to self-monitor one or more parameters associated with a product can be sent to "interested parties". There is, however, no mention of the interested party's aim use of the PUI in relation to the autonomic logic for self-monitoring.

There is, moreover, little mention of a generic approach to linking PUI via software tools to support or deliver product extension services. [16] acknowledge the emergence of these solution components as *"intangible extended products, which are information and knowledge intensive and can consist of services, engineering, software, etc."* [17] include immanent software components as an integral part of their definition of IPS[2]. Outside of these publications, there is little mention of IT-based or software-supported product extension services, and no investigation of integrated PSS design or development processes including software components.

III. Initial Use Cases

In order to design a methodology for the selection of PUI sources for the (re-)design of Product Service Systems, a thorough understanding of both the general knowledge domain of PSS and specific PSS characteristics is required. To achieve a general understanding, a study of the field of PSS is being carried out. In addition, to understand the needs of specific PSS providers, an initial set of five different PSS business cases have been selected. These business cases encompass a wide range of different consumer and business-to-business PSS, as follows:

The aim of the white goods use case is to improve the user-experience of washing machines through an anticipatory service approach. PUI gathered through sensors (water level, water hardness, etc.) and WMAs digitized using Product Embedded Information Devices (PEIDs) shall be processed to optimize maintenance and repair processes. Another aim is to enhance the user experience by supporting the user in determining appropriate detergent and softener dosing, based upon usage and washing process data.

A brown goods use case aims to offer improved customer experience and innovative connected applications, to reduce time-to-market of improvements and new connected applications, by analysing PUI generated during the use of a smart television and by interaction with its user interface.

The main goal of the clothing textiles use case is to improve the customers' experiences of buying cashmere clothes by helping them find the requested garments. To achieve this, the customer comments, searches and propositions on online platforms will be analysed. This allows the manufacturer to understand which garments are requested by the customer, how they can be combined, proposed, described and modified, thus anticipating next season's trends and support the ideation of collections.

PUI from the operation of high-tech products (e.g. 3D-laser scanners) and software shall be collected to design customer-tailored products and services. Feedback from PEIDs and customers through helpdesks, meetings etc. shall be collected and analysed.

For medical equipment, PUI will be collected via PEIDs and software sensors about the experts' use of the products. Ergonomic improvements as well as optimised services for the assistance of the experts use of the products will be tailored based on the usage patterns exhibited by the PUI.

IV. Target Methodology

The overall aim of the methodology is to guide PSS design experts through the process of selecting PUI sources for the (re-)design of product service extensions. That means, by looking up a specific product service extension, the PSS designer should be presented with a selection of PUI sources which can support the required service. The reverse should also be facilitated by the methodology: by proving existing PUI sources (e.g. sensors embedded into an existing product), the PSS designed should be given an overview over which types of service can be supported by the PUI sources.

The methodology can be realized only if a comprehensive PSS model is available in which PUI sources are formalized and mapped to related services. Due to the diversity of PSS and the wealth of potential PUI sources, such a model would be extremely complex. In order to limit the complexity of the PSS model, an approach has been chosen by which the overall PSS knowledge domain is modelled as an ontology, which can be extended by specific PSS sub-ontologies as required. This means that the model need not cover all potential permutations of PSS and PUI sources at first, but can be extended to cover whichever PSS domain is required. Common concepts (such as common types and characteristics of PUI) can, however, be abstracted into the general PSS upper ontology to be reused by each domain-specific one. An initial version of concepts modeled in the PSS upper ontology is shown in Figure 4.

To provide the functionality required, it is however necessary to accurately and comprehensively model each individual PSS domain which a specific focus on which PUI can support which service.

The semantic models of the individual, specific knowledge domains are initially being implemented based on the initial use cases described in Section III. To model the individual PSS knowledge domains, the User Story Mapping (USM) method [18], is being applied. This method from agile software development is a user centric method, which allows the designers of software to learn about what future users expect, besides helping the users express their overall demands in a functional view which is common to them. After the application of the USM, detailed and structured information about knowledge present in the domain is available, as well as how it is exploited and exchanged between actors. Creating concepts requires recognizing leading objects and factors that will be translated directly into concepts. For example, in a manufacturing company, the term "machine" will be present in a number of user stories, so it is clear that the ontology will contain the concept "Machine". This concept will model all the knowledge about one machine, as well as its usage and functionalities.

In addition to the core general PSS upper ontology and domain-specific ontologies, a software tool will be designed and implemented which is able to make recommendations based on semantic reasoning. This software tool will be able to guide the PSS designer through the process of either selecting which PUI source to use for a pre-determined service, or suggest servitization options for the current PUI sources of a given product or PSS. This way, PSS designers can intuitively make use of the ontology without detailed knowledge of semantic modelling.

V. Outlook and Discussion

An initial study following the K-Brief methodology in the EU H2020 project FALCON has indicated that the involved industrial partners see great value in a methodology for selecting Product Usage Information sources for the (re-)design of Product Service Systems. Such a methodology could fill the gap in a systematic understanding of how PUI relates to value-added services and what types of servitization strategies are available, making it easier for companies to servitize physical

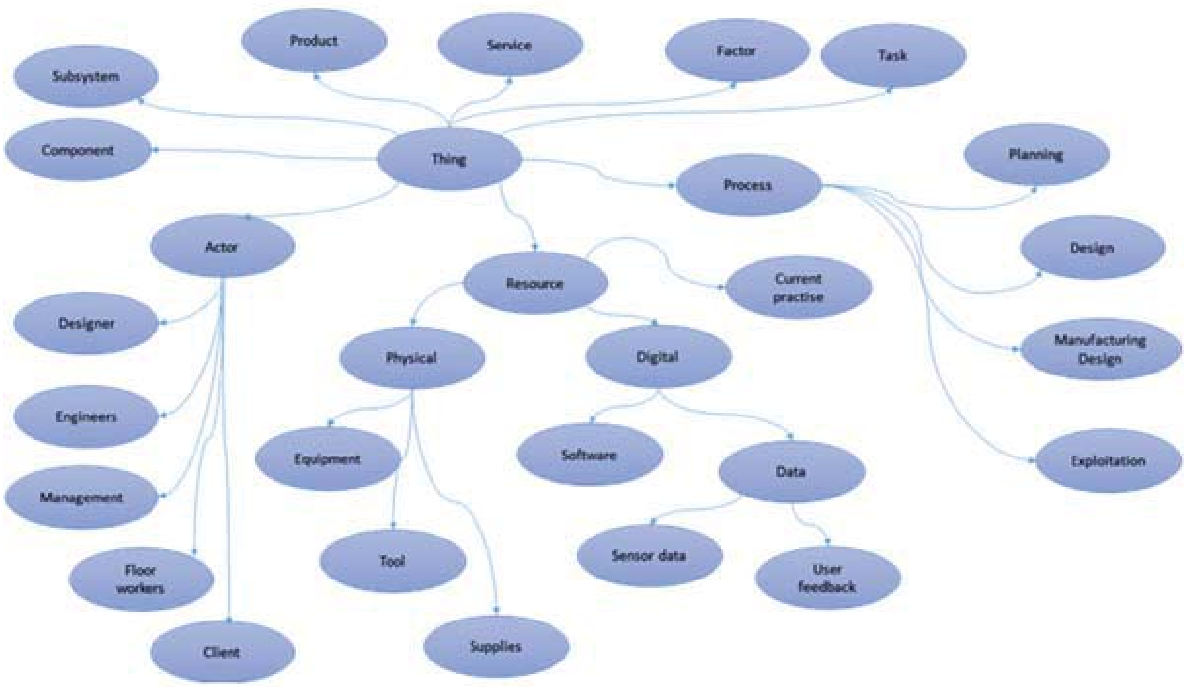

Figure 4: Initial PSS upper ontology concepts

products, exploit existing PUI sources and create additional revenue streams for existing products. However, the complexity of the relations between PSS, their lifecycles and PUI must not be underestimated. A significant risk lies in the danger that a comprehensive semantic model of PSS in its relation to PUI could be too complex to efficiently support such a methodology. However, the authors are confident that by separating the general PSS upper ontology from domain-specific PSS models, that complexity can be managed whilst simultaneously retaining its value for different sectors by focusing on extensibility.

In addition to mapping PUI sources to services to make easier the design of product service extensions, the methodology may be extended by further elements. Particularly relevant to PSS design based on PUI feedback loops are the methods and algorithms of analysis which are used to filter, aggregate and process the PUI to provide actionable knowledge for PSS design experts. The authors will consider the inclusion of this element. However, this will mean increasing the complexity of the methodology even more, which may reduce the value of its applicability.

The next steps in the present research work are to finalize the PSS and domain specific models. After that, suitable tools will be designed and implemented to support the methodology based on the ontology. Finally, the methodology will be validated using the PSS business cases outlines above.

ACKNOWLEDGMENT

Part of this research has been funded under the EC Horizon 2020 Programme, in the context of the FALCON project (http://www.falcon-h2020.eu/). The authors wish to acknowledge the Commission and all the FALCON project partners for the fruitful collaboration.

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