Collaboration Driven Requirements for a Product-Service Engineering Platform

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Abstract. Modern manufacturing and business based on product service systems require software platforms capable of supporting offerings over their lifecycle thus securing long term customer value. Also a function to get and manage feedback from end users, customers and manufacturing is essential for design to build in functionalities and features that best enable efficient use and maintenance. The aim is to integrate the Product Life-Cycle Management (PLM) and Service Life-Cycle Management (SLM) concepts resulting in a coherent and collaborative Product-Service design and manufacturing engineering platform. The concept requirements were collected from four real world use cases and refined and combined to create final set of requirements. In this paper we present the facilitated requirement collection process and the final requirements in relation to engineering collaboration and product-service system characteristics.

Keywords: Product-service engineering · Requirements engineering · Platform for collaboration · Manufacturing intelligence · Use cases

1 Introduction and Objectives

Business based on Product-Services (P-S) is a reality today and such business continues to grow, both in the business-to-business sector as well as in the business-to-consumer sector. Car sharing is an example of this type of business that today is available in many cities. The same trend also takes place in the manufacturing sector, which is a phenomenon referred to as servitization. The EU H2020 Manutelligence project [1] aims at supporting this trend, allowing enterprises to develop sustainable innovative P-S efficiently addressing customer needs.

Some of these services can be provided only after punctual and accurate analysis of customers' product usage in order to acquire useful information for new product improvements or services provision. Often the misalignment between the product and service development processes and incapability for concurrent engineering between both processes arise due to the lack of information exchange among the product and service life cycle phases. Therefore more attention must be paid on P-S evolution along the entire value chain. The aim is to integrate the Product Life-Cycle Management

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(PLM) and Service Life-Cycle Management (SLM) concepts resulting in a coherent and collaborative P-S design and manufacturing engineering concept.

The collaboration platform in Manutelligence will build on an existing commercial PLM software solution enhanced with additional features for P-S engineering, Internet of Things (IoT) support and life-cycle assessment. The platform will enable designers and engineers to access data from both the traditional enterprise IT systems and IoT enabled systems. The objective is to manage manufacturing intelligence; all data, information and knowledge related to the P-S and its lifecycle.

An extensive requirements engineering and elicitation process has been undertaken in the Manutelligence project. The process and its justification as well as detailed data have been presented in the project deliverables [2, 3] and earlier articles [4, 5] and will not be studied in detail in this paper.

The user-centric perspective is important, both in terms of greater attention to the end customer requirements (use and goal oriented approaches) and an easier involvement of customers in the P-S co-design. A lack of user-centric perspective may easily lead to innovation resistance as the designed P-S does not fit customer needs [6]. Four real world pilot use cases form the basis for collection, structuring and analyzing user requirements for the P-S engineering platform. The cases that come from different industrial fields are of different sizes from multinational manufacturing companies to SMEs, the knowledge standards and the preparedness for adopting innovative approaches are on different levels. The pilots [2] cover some of the main European manufacturing sectors, e.g. automotive, marine, construction and additive manufacturing.

The paper will elaborate on and answer the following research question: What are the collaboration driven requirements for a product-service engineering platform? This is answered based on the data from the Manutelligence project.

The next Sect. 2 recaps on some previous research in the area of Collaborative Networked Organisations, P-S engineering, platform approaches for P-S, and Co-development. Section 3 presents the used requirements engineering methodology. The identified collaboration platform requirements are explained in Sect. 4. Conclusions and ways forward form the final Sect. 5.

2 Collaboration in Product Service Lifecycle

Collaborative engineering of P-S covering all life-cycle phases is an indeed demanding process. To come up with efficient solution we need a multi-disciplinary approach. State-of-the-art research progress and solutions must be capitalized from several fields of activity, e.g. Collaborative Networked Organisations (CNO), P-S engineering and P-S Life-cycle assessment, Internet of Things (IoT), Collaborative Platforms and Co-development. Manutelligence will improve the product and service development by connecting them together through cross-disciplinary feedback loops by means of modular collaborative secure ICT manufacturing intelligence platform. It will be possible to use the platform for the design of a product from the first life-cycle stage onward so that it acts as an enabler for multiple services on top, and for designing and developing new innovative services based on the existing products, for developing new products and tailored services based on product usage information and customer's wishes, and for collecting usage and operation data of the developed P-S. Thus the requirements identified in this paper are not the requirements of the P-S systems [7, 8] but the requirements for the platform used for their design and management. The paper presents the new case based user requirements to the platform. "The idea was not to collect all the potential functions that an engineering platform could cover, but to identify new needs with relation to their current tools and practices." [4]

2.1 Collaborative Networked Organisations

Much knowledge and understanding of CNO has been acquired through European Union supported research during the last decades. There have been a multitude of research initiatives in Europe in the field of CNOs [9] and also in the context of global co-operation [10]. The research objects span from traditional supply chains, collaborative networks and business eco-systems to virtual organizations.

In CNO research, two main concepts for inter-enterprise collaboration are often referred to. According to the objective and duration of the collaboration the two concepts are [11]:

- Network/Breeding environment which is a more stable, though not static, group of organisations which have developed a preparedness to co-operate.
- Virtual organisation (VO)/Virtual enterprise which is a temporary consortium of partners from different organisations established to fulfil a value-adding task, for example a product or service to a customer.

Accordingly, a VO is usually created within a network composed of organisations committed to collaborate. To achieve efficient collaboration, some degree of preparedness is needed. This preparation takes place within the Breeding Environment. The concept of the Breeding environment is used to characterise the network behind a VO. The Virtual organisation's Breeding Environment (VBE) represents a long-term "strategic" alliance, cluster, association, or pool of organisations that provides the needed conditions for collaboration [9].

The CNO concept has also been used for special purposes and application niches, for example; offering opportunities to provide aging care and elderly population assistance [12] and to promote the sharing and recycling of resources such as: information, materials, water, energy and/or infrastructure with the intention of achieving sustainable development in a collaborative way [13] as well as to effectively support the delivery of highly customized and service-enhanced products along their life-cycles [14].

2.2 Product-Service Engineering

The business approaches of service delivery as an integrated part of product is a vast research topic. Manufacturers are moving more towards the business approach of P-S in order to achieve new customers and increased sales. P-Ss have many advantages such as achieving closer customer connection and generating increased profit from manufactured products. The importance of services is also recognized in the marketing field. According to Vargo and Lusch [15] there is an emerging trend in the marketing and business thinking of firms where firms are moving from traditional goods-dominant logic (G-D) to service-dominant logic (S-D). In the G-D logic, customers are seen as targets for which value is created through transactions of products and services. In the S-D logic, customers are active participants in networks of value creation where value accrues to each actor as they integrate resources in their own use contexts. According to a study [16] based on broad empirical interview data, four types of open innovation with customers are identified to categorise product and service providers through their main business and innovation logics and relating customer involvement of companies. The types are customer-oriented providers, customer-solution integrators, developer partners, and facilitators of co-innovation.

According to [17] the following grouping of product/service systems is frequently used:

- Product-oriented Services: The product is owned by the user/consumer.
- Use-oriented Services: The product is owned by the service provider, who sells functions; for example, sharing, pooling and leasing.
- Result-oriented Services: The supplier provides incentives for the customer to consume services by using results orientated payment systems.

2.3 Platform Approaches for Product-Services

Globalization of production and growing level of outsourcing has been supported by information technology development. P-S over its lifecycle has been affected quite unevenly by this. The Beginning of Life (BOF) phase functions like R&D as well as End of Life (EOL) services like maintenance have been impacted less than more mechanistic production, especially in the goods industry. “The smiling curve” [18–20] is a term commonly used to represent this change of balance of value in favor of services over goods. Currently IoT and cloud based digital platforms are some of the most topical paths of progress, pushing servitization in industry.

Digital platforms are “information technology systems upon which different actors – that is, users, service providers and other stakeholders across organizational boundaries – can carry out value-adding activities in a multi-sided market environment governed by agreed boundary resources.” [21].

Industry platforms are products, services or technologies that are similar to the former but provide the foundation upon which outside firms (organized as a “business ecosystem”) can develop their own complementary products, technologies, or services [22].

2.4 Co-development

As brought up by von Hippel [23] in addition to manufacturers, development work and innovation is often carried out by suppliers and especially users. For this reason, companies have lately involved customers in their development efforts and instead of conventional market research many companies utilize the lead user method in their development efforts. Customers are often involved as informants, ideators and developers; but their involvement also helps (1) to shape the overall context where the value of P-S is created, (2) to foster network effects that guide the diffusion of P-S innovation, (3) to cope with contingency in P-S development and adoption, and (4) to engage customers in business that is meaningful for them [24]. However, involvement of customers in P-S development is costly both for providers and customers and it also leads to some extent of loss of power from the P-S provider to the customers. That is why many companies involve their customers in P-S co-development through innovation toolkits that reduce the costs of customer involvement and simultaneously limit the design scope. The design scope of innovation toolkits is also often limited to functionality offered by a single provider company alone. Co-development together with customers, suppliers and other stakeholders is particularly important when developing P-S for ecosystems contexts as the customer needs in an ecosystem depend on the actions of the other ecosystem members [25]. A collaborative platform like Manutelligence could provide many of the benefits of innovation toolkits with a wider design scope.

3 Methodology

The identification of collaboration needs and requirements for the intelligent platform is based on four industrial pilots. The process started with the creation of a "Pilot Story" for each pilot. The pilot story is a free text description of a fictive, future situation, when all the needed functional requirements are implemented and fully used, written in co-operation with the end users.

Based on the pilot stories more structured business scenarios and use case descriptions were created. A use case is an interaction with systems. The use cases describe the series of steps that take place during the interaction and include different ways that this interaction could play out. The scenarios and use cases were used as a starting point for requirement engineering.

The process to analyse the collaboration related requirements had two phases. First phase was for the requirements engineering (RE), resulting into aggregated requirements, and the second for identifying the collaboration driven requirements from the list of aggregated requirements. The chosen RE iterative model is based on the classical spiral methodology in which each iteration circle goes through the main four phases that compose the requirements process: (1) Elicitation, (2) Structuration, (3) Analysis and Refinements and (4) Validation, as illustrated in Fig. 1 [26]. In each phase of the RE process the P-S dimension is taken into account in order to ensure the integration of the services from the very beginning of the development.

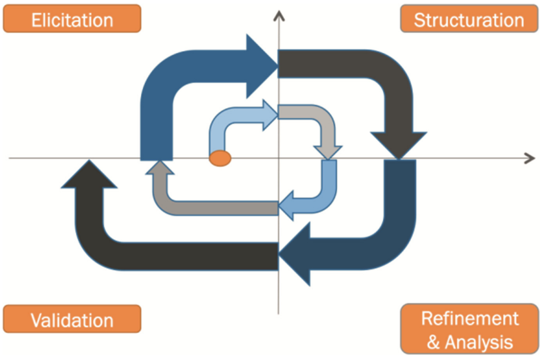

Fig. 1. Used requirements engineering process methodology. (Source: [26], p. 18)

All the cycles are the same except the first one because it has the role to initialize the process. Then the other cycles represent the continuous improvement of the requirements. This paper considers only the initialization phase because the further iteration cycles will be completed later on in the project. The four RE tasks of Manutelligence are:

- Elicitation: the elicitation is concerned with the identification and analysis of the real-world requirements. Heterogeneous opportunities coming from different stakeholders were identified. A list of unstructured requirements was created.
- Structuration: the main objective of the structuration was to unify and integrate the information collected in the previous step from disparate sources and organize them into a common structure that can be used for analysis.
- Refinement and Analysis: the target is to refine and verify the structured requirements. It consists of the assessment of the completeness, coherence and feasibility of the stakeholders' requirements. The refined technical requirements are subject to a prioritization process.
- Requirements validation: the validation purpose is to show the actual requirements to the use case stakeholders in order to understand if the actual definition fits their needs.

After these steps, the aggregated and validated requirements were retrieved. In the second phase the identification of the collaboration driven requirements was done by the authors. This took place in a group discussion and was based on two criteria a requirement had to fulfill: requirement had to be about collaboration between actors not just between an actor and the platform, and requirement was not to be focused on a single technical functionality but a systemic feature.

4 Platform Requirements Related to Engineering Collaboration

After the requirements engineering process 21 aggregated requirements were identified and listed. [27]. For the purpose of this paper the aggregated requirements were further analysed by the authors to select those mostly related to the engineering collaboration. The selected four aggregated requirements are presented below and unfolded including the most relevant topics originating from the unstructured requirements. The selection does not mean that there is no collaboration need in the remaining requirements.

4.1 The Collaboration Network and Community of Designers Shall Be Able to Support and Contribute the Design on the Platform

Design and engineering can be considered a multi-x activity: it requires the knowledge of multiple technologies (like mechatronics, electricity, software, services…), multiple partners are needed, it is performed multi-site. Products are often very complex and there is a pressure to shorten the design time. Efficient collaboration in the design process is needed to enable concurrency. The needs of collaboration in the design/engineering extend from being able to view the up-to-date design, through giving comments from another viewpoint to supporting the editing of the CAD design or product model. In some cases (like FabLab) an open community of designers may exist, which may guide the designer in product modelling. In distributed networks and organizations this requires efficient communication between partners and access to the same data. To make this collaboration effective the platform should provide access to the registered users to both support and contribute to the design.

4.2 The Customer Shall Be Able to View the Visual Product Model (Including Virtual Walk and Driving) and Give Feedback on It Using the Platform

When developing complex products and related services, it is important to get customer feedback to the design continuously along the design process. This requires that the P-S platform offers easy-to-use and illustrative visualisation of the design to the customer(s). Currently customers typically use only the traditional 2D drawings and they need to visualize the final product in their mind. The virtual reality 3D models are becoming more and more common in many industries but they are usually separate software packages. This requires discrete conversions and thus up-to-date drawings are not constantly available. A platform with integrated 2D/3D conversions and rendering provides a tool to accelerate customer collaboration over the design phase. To be useful the platform also has to provide user-friendly and efficient customer feedback reviewing tools. For example, the platform should allow the customer to give the comments and change requests directly to the visual product model. There are different types of P-S customers, like end users (not owing the product), product owners and service providers. These different roles may require and offer different viewpoints to the design which needs to be taken into account when developing the feedback mechanisms. Additionally, it is important to define the processes and responsibilities for how the customer feedback is handled in the design team.

4.3 The Production Personnel Shall Be Able to Use the Product Model on the Platform to Support and Monitor Production, Installation and to Give Feedback for the Design

Production personnel have both task specific knowhow and first row view to design implementation challenges. To enhance the exploitation of this immaterial capital the platform has to provide functionalities that support communication with design. There are multiple opportunities how the platform could support the production and the communication to design, using the visual product model. The production personnel may give comments to design related to the manufacturability, they may use the model to support the installation or to monitor the status of manufacturing, installation or inspection activities. To be efficient production personnel needs access via the platform to the supplier product data base (catalogues), production cost tracking and data linked to the model elements.

4.4 The Platform Should Support Sharing and Communication, also Remotely, Online and Off-Line

As a whole, the P-S lifecycle requires collaboration between different parties. In some cases open communities are built around the manufacturing activities. The platform needs to support the different levels of communication and sharing of data and information. Working life is moving towards networked organizations and place independent work. Remote work both online and off-line should be possible. Specifically off-line is critical since 24/7 online access to the system can often not be guaranteed nor be feasible also from the data transfer or security point of view.

5 Conclusion and Ways Forward

Though ICT platforms for design and manufacturing have recently evolved substantially, there are only few solutions that integrate all tools and phases over both product and service lifecycles. In Manutelligence many requirements based on use cases have originated from the challenges of accessing and sharing information across lifecycle phases. Especially design and design related tasks have been distributed globally. This trend has been enabled and pushed by the ICT. However the ability to transmit data from one continent to another as easily as within one office has not solved all challenges but actually created new ones. This new operational environment requires new ways of doing and sharing the work not just data.

Based on the findings presented in this paper the requirements are linked to several major elements of business; customer, design, manufacturing and ways of working. Thus it can be deduced that a holistic perspective is needed to secure maximum benefits from the new integrated platforms. If focus is on optimising individual tools and methods the efficiency of data and knowledge management processes required over lifecycle by an integrated P-S system is not attainable.

Our conclusion is that the ecosystem collaboration is essential in P-S lifecycle and it could be enhanced with a P-S platform which allows sharing, visualising and commenting manufacturing intelligence, including all information, models and data related to the P-S and its realization.

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