How to Support the Design of User-Oriented Product-Related Services

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Abstract. A Product-Service System (PSS) is an innovation strategy, shifting the business focus from designing physical products only, to designing a system that combines tangible products, intangible services, supporting network and infrastructure, which are jointly capable of fulfilling specific customer needs. Due to the widespread of this paradigm, the present research provides a methodological framework and related tools to support the design of PSSs. The aim is to propose a user-centered approach to involve end-users during the different stages of PSS development.

Keywords: Product-Service System · User-Centered Design · Hardware-in-the-Loop · Virtual reality

1 Introduction

With the popularity of pervasive Information and Commutation Technologies (ICT) (e.g. wireless networks, broadband), products are become more "intelligent" and capable of communicating with the surrounding environment, storing data, interacting with other connected devices, until being adaptable to the user needs, behaviours and attitudes, as well as developing more strategic marketing actions. There are numerous examples in literature of products integrating an Intelligent Data Unit and service enabler software to elaborate lifecycle data and share information and knowledge [16]. This technological trend pushes towards the development of product-related services and the creation of the so-called Product-Service Systems (PSS), which add a wide range of services to the customer, from remote assistance to preventive maintenance, training, retrofitting and product monitoring [13]. Most researches focus on the description of PSS solutions in different application fields, embedded technologies to enable product-related services, methods of data acquisition and elaboration, and software interface [6]. However, the focus on technology often neglects the final customer needs. Indeed, only few of them face the problem of how to develop a PSS applying a User-Centered Design (UCD) approach to create a really customer-oriented and adaptable service [8] and, finally, how to create effective and efficient models to identify usability problems at the different stages of PSS design [14].

N. Streitz and P. Markopoulos (Eds.): DAPI 2016, LNCS 9749, pp. 103–110, 2016.
DOI: 10.1007/978-3-319-39862-4_10

The paper illustrates two case studies of PSS for household appliances, where traditional low-fidelity prototyping techniques are used. Experimentations demonstrate the difficulty to effectively design the product-service features predicting User eXperience (UX) by traditional tools and methods. The main problem is that product and service are usually designed separately on diverse mock-ups and the final PSS performance is achieved only when the first physical prototype is developed. In order to solve such limitations, a UCD approach is adopted to define a novel virtual prototyping system architecture that allows developers to create interactive mock-ups of the entire PSS to verify step-by-step the achieved performance and users' satisfaction. It helps to design both product and service features taking into account the reciprocal relationships and the final performance of the integrated PSS.

2 PSS Design and Prototyping: An Overview

A first question to face PSS design regards what PSS is. Most researches agree in defining PSS as an innovation strategy, shifting the business focus from designing a physical product only, to designing a system of products and services which are jointly capable of fulfilling specific client demands [5]. It implies the combination of products, services, supporting networks and infrastructure to guarantee company's competitiveness and customer satisfaction [7]. For the customer, a PSS is seen to provide value trough more customization, additional functionalities and higher quality to suit his/her needs.

In this context, technical services represent the easiest way to create a PSS in manufacturing industry: from maintenance to training, retrofitting and product monitoring. Indeed, they can be easily realized by improving the product communication capabilities in order to make data flow from product to external systems to realize supporting or differentiating services. This integrated understanding leads to new and customer oriented solutions, and enable innovative functions and result-oriented business models. Furthermore, services can bring great advantages for industry: from the economical viewpoint, services can create higher profit margins and contribute to higher productivity by means of reduced investment costs along the lifetime as well as reduced operating costs for the final users [1].

One of the widely recognized barriers to the adoption of PSS and the achievement of an effective PSS regards the relationship between the customer, who is the final user of the PSS, and the company network, which is the entity providing the PSS. The early involvement of customers in the design process is essential to achieve a successful solution, able to respond to customer wants and needs. This means to involve end-users into a co-creation process in PSS designing [4]. However, the creation of physical prototypes, including the product and the service, reliable enough to be used for usability testing with sample end-users is generally costing and can be done only once the design process is at an advanced stage. There are a variety of tools and methods to support the design of a PSS in literature. Most of them are tailored to specific projects, exploit well-known principles of Concurrent Engineering, Systematic Engineering and recently User-Centered Design approach, and hence include the following stages: identification of customer value, early involvement in the system design, information sharing and continuous design improvement [10]. Mont [7] argued that a further development in design methodology is necessary to promote the implementation of PSS. In terms of approach, the greatest reported challenge is to engage relevant stakeholders in the process of research, evaluation, and testing at both theoretical and practical levels [1]. In industry, this means that long-term and integrated testing of PSS practice is needed to help to develop theories, methodologies, and operational solutions. Advances in Virtual Prototyping techniques allow the creation of realistic, reliable and enriched high-fidelity virtual prototypes able to simulate the product in different working conditions [15]. Benefits in adopting VP to involve the end-users at the different product development stages are well known in literature and proved by numerous reported applications [12]. The introduction of a service jointly operating into a product is a challenging issue both in VP and in PSS development. While numerous tools are actually developed to model a PSS, none specific platform to support virtual prototyping have been yet created.

3 Case Studies to Explore PSS Development Issues

Two case studies of PSS development are here described to point out the main critical issues to be faced in terms of design and prototyping solutions centered on customers.

Both cases regard a PSS where intelligent appliances (i.e. washing machine, washer-dryer, oven, fridge) are able to collect data about their functioning, connect to an Home Area Network (HAN) based on ZigBee technology and to the Internet to make data available for both a local Home Automation Controller and web-based services (Fig. 1).

The first case developed a domestic Energy Monitoring Service to monitor and manage the power consumptions of connected appliances: each appliance communicates its consumptions and operating status to the Controller, which allows to display the instant power consumption and to set the optimal configuration; contemporarily, the manufacturing companies can monitor the consumption data, detect dangerous situation and provide remote assistance and maintenance services.

The second case concerns the ideation of a Carefree Washing Service where product monitoring is not limited to energy consumption, but includes also product behaviours (e.g. programs, temperature control, water and soap control if needed, etc.) and detection of dangerous situations, and services are extended to smart maintenance that comprehends personalized advices like usage best practices and marketing proposals (coaching service) and technical best practice to prevent or handle with faults (fault management). Data are monitored by specific sensors and collected in a database; a set of elaboration algorithms analyses these data according to two policies (i.e. coaching and fault management) in order to recognize the specific use scenario and support the user with personalized and tailored suggestions and advices. A web/mobile application provides personalized messages directly on their mobile phones [9].

In both cases, PSS have been defined according the design methodology proposed in [10], which allows identifying product and service functions as well as needed assets and partners. It starts from market analysis and identification of the users' needs and demands, to the definition of the user tasks, requirements elicitation, definition of the PSS functions, assets and technological partners.

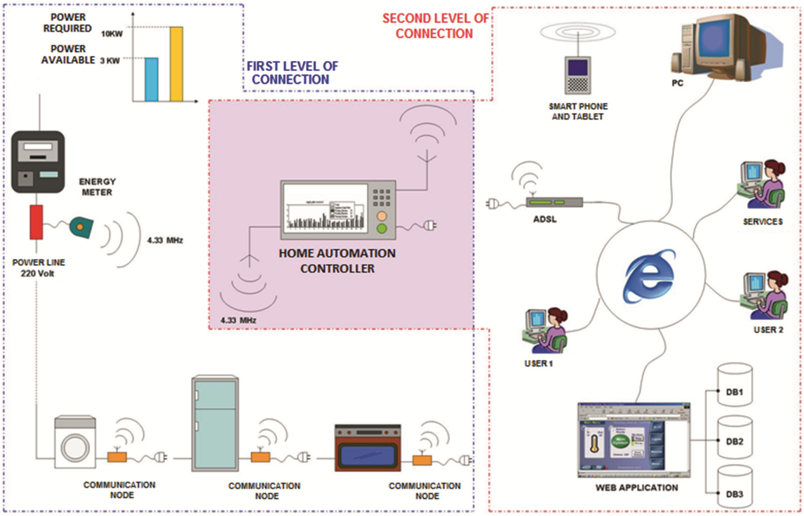

Fig. 1. The PSS reference system architecture for household appliances

The first PSS (Energy Monitoring Service) has been tested on low-fidelity prototypes based on mixed reality techniques [2]: it merges rapid prototyping and augmented reality to represent the achieved design solution and perform usability testing with low time and cost (Fig. 2a). The second PSS (Carefree Washing Service) used high-fidelity prototypes: the product was prototyped physically reusing parts from existing products and prototypal new components, service platform was developed as a prototypal application and user interface was created in Silverlight (Fig. 2b).

2a. Low-fidelity prototype of Homeline PSS exploiting Mixed Reality techniques

2b. High-fidelity prototype of Carefree Washing Service as Web application

Fig. 2. PSS prototypes in both case studies

4 The Framework to Prototyping User-Oriented PSS

A new design methodology is defined to support PSS as synthetized in Fig. 3. It uses role-playing for UCD study of users' needs, Business Use Case (BUC) modelling for the analysis of PSS scenarios', Quality Functional Deployment (QFD) for the correlation between needs and functions, Computer-Aided system to design the geometrical, aesthetic and graphical aspects of both product and interface, DMU for modelling the PSS behaviours, HIL approach for PSS simulation in a VR environment.

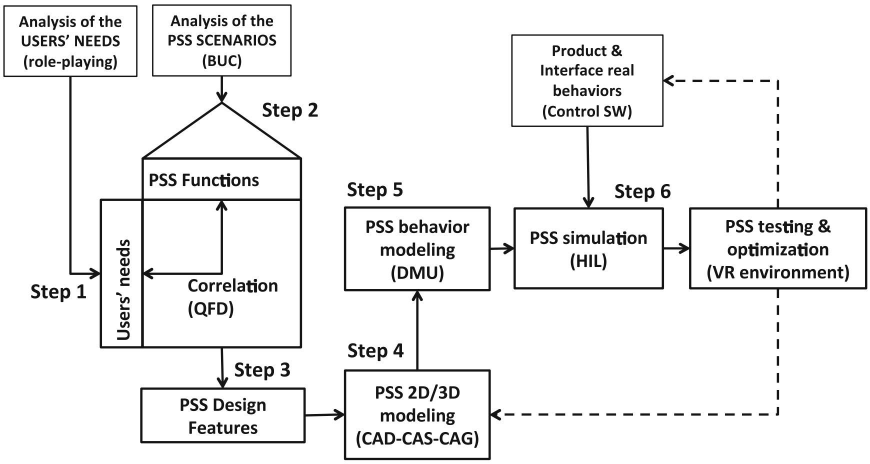

Fig. 3. The design methodology for PSS based on DMU and HIL

The PSS simulation platform combines the system digital mock-up (DMU) with the so-called Hardware-in-the-Loop (HIL) approach [3] to create a realistic prototype able to simulate the product and service behaviours in real time thanks to the communication of the virtual model with the real control software. Such an approach has been used for virtual simulation of mechatronic systems since it should be quickly configured to follow the customer requirements, and then even reconfigured in case of new production demands. For PSS it can be used to achieve a reliable and real-time behaviour simulation like on physical prototypes, but limiting time and cost and improving the flexibility, since a lot of alternatives for the product-related services can be simulated just changing the software control.

Figure 4 represents the architecture of the PSS simulation platform for usability testing. The product digital model is defined by using a CAD system (CATIA) while the service interface is defined in graphics and dynamics by commercial tools (from Power Point to Flash). Product-Service behaviours are modelled as a DMU by dedicated software (DELMIA) and a library of behaviours for different user profiles is managed as DBs. On the other hand, the real main board is connected to a simulation PC that is the controller, which is connected to the digital mock-up. Thanks to HIL software (VIRTOUS) [11], the simulation PC controls the digital model; after that, such a model is managed by VIRTOOLS platform to create a virtual simulation environment within

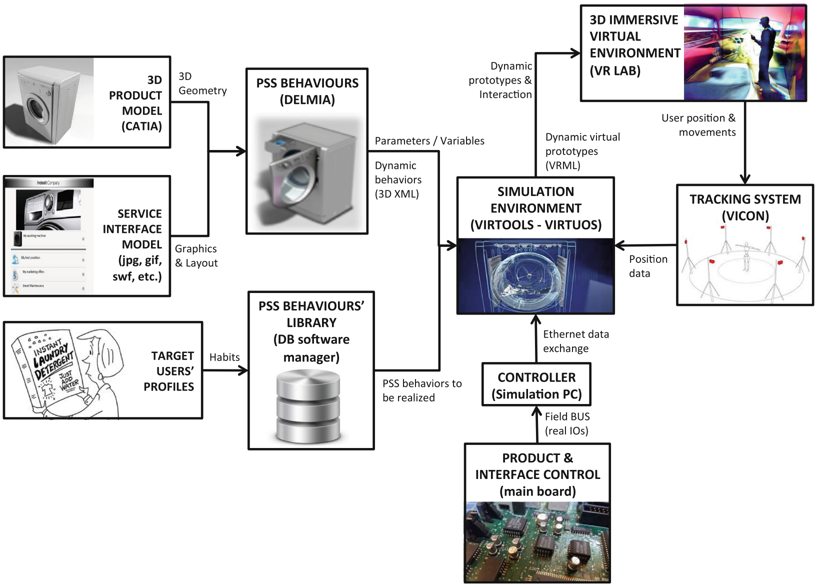

Fig. 4. The architecture of the PSS simulation platform for usability testing

a VR Lab enhanced with immersive stereoscopic viewing, tracking system and devices for interactive human-product interaction.

The tracking system (VICON) allows monitoring real users during simulation and configuring the PSS behaviour according to the users' actions. Data will be exchanged via 3D XML and VRML to create an interactive virtual prototype, and Matlab/Simulink can be integrated into the VIRTOUS model to implement complex system controls. In more details, Fig. 5 shows the data flow during the simulation.

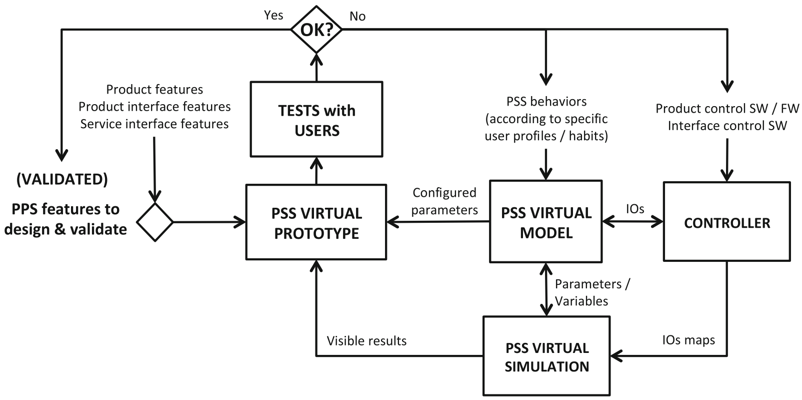

Fig. 5. Data flow for PSS virtual simulation

The critical points in the development of the proposed system will be the real-time interaction between the HIL system (VIRTUOS) and the real PSS controller, and the integration of VIRTUOS within the VIRTOOLS platform.

5 Conclusion

A methodological framework to support the user-oriented design of PSS is proposed. It directly starts from the difficulties faced in two industrial case studies focusing on the development of PSSs. In both cases the manufacturing company network outlined problems related to the definition and subsequent evaluation of the user experience generated by the conceived PSS, to the complexity to predict the PSS behaviour during the design stage and finally to assess the quality of the interaction with the final user only when a first prototype has been realized. Thanks to these past experiences, a proper framework to model and simulate the PSS during the design stages is proposed in this paper. It aims to overcome the identified difficulties and innovate current state-of-art in Virtual Prototyping and PSS tools. It exploits different software tools (i.e. CAD modelling, virtual prototyping developing platform, system simulation) to create an interactive virtual prototype of the conceived PSS that can be used to involve sample end-users to test system usability and PSS performance. Such an approach avoids the construction of costly physical prototypes that combine both service and product features, and greatly reduces the time spent for PSS optimization at the end of the design stage. Furthermore, the level of usability and user satisfaction achieve was higher than in past cases.

The main drawback of the designed platform is systems' integration and tools' interoperability. Future research work will be focused on the implementation of the platform by creating proper interfacing plug-in applications and on the adoption of the overall framework in real case studies. The collection of end-users feedbacks will allows developers to improve the platform functionalities and making it useful for designers to achieve high PSS quality.

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