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USER-CENTRED APPROACH FOR PRODUCT-SERVICE DESIGN USING VIRTUAL MOCK-UPS

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1. Introduction

For modern companies, offering product-service solution represents a widespread tendency to add value to existing products, create a new value proposition with low effort for the producing company, and better satisfy the market needs, as stated by Goedkoop et al. [1999]. It consists of adding services to physical products in order to offer new personalized functionalities and specific behaviours to better satisfy the customers' expectations, by a new offer: the so-called Product-Service System (PSS) [Thoben et al. 2001]. Such a trend is becoming relevant for manufacturing industry due to the diffusion of pervasive Information and Communication Technologies (ICT): indeed, ICT can easily create an higher service layer able to enrich simple products with new "intelligent" behaviours and communicating capabilities (i.e. monitoring the surrounding environment, monitoring the users' habits, interacting with other connected devices, being adaptable to the user needs, behaviours and attitudes) [Yang et al. 2009]. However, designing PSSs represents new challenges for manufacturing companies, which are involved in the design of no more single products, but a set of integrated and complex systems, providing functions by combining physical devices and intangible assets as well as specific software tools and a proper supporting infrastructure. In literature, several methodologies have been recently proposed to manage the different design stages of an industrial PSS [Wiesner et al. 2013], [Kimita and Shimomura 2014], [Peruzzini and Germani 2014]. Althought human-centred disciplines such as ergonomics, usability and user experience have been introduced in product design, PSS design is still intensely technological-driven: as a result, PSSs are usually designed by following technical drivers and, only when a first prototype is realized, functionalities are tested with users. Generally, numerous usability problems emerge at this stage, when every engineering change is time-consuming, expensive and rather limited because the technological infrastructure has already defined.

The present research defines a user-centred design methodology for PSS, which combines service-oriented methodologies with User-Centred Design (UCD) practices: the former allow to elicit PSS functions, while the latter to investigate the users' needs by also interactive virtual mock-ups able to simulate both product and service behaviours and interaction with potential users during the design stages, in order to simulate in advance the PSS behaviour and to check its appraisal by involving final or sample users'. As a consequence, the new method allows the PSS features to be optimized before real prototyping, when design modifications are easier, faster, more effective, and less expensive.

2. Research background

2.1 Product-service systems design

In order to move from product design to Product-Service System (PSS) design, traditional

manufacturing companies are required to change approaches, processes and business models to move towards the so-called Servitization process and become more service-centric [Thoben et al. 2001]. In this context, the investigation of the customer needs and its translation into system requirements is a crucial task, and different approaches have been defined for requirements elicitation (RE): Quality Functional Deployment (QFD) can be used to map the customer needs with the PSS functions by a set of Houses of Quality (HoQ) [Matzler and Hinterhuberb 1998]; Design Structure Matrix (DSM) can exploit the multi-level analysis to define the main PSS functions [Eppinger and Browning 2012]; Business Use Cases (BUCs) analysis can support the definition funzional use cases and goal-oriented interactions between actors [Peruzzini and Marilungo 2014]; and Serious Games can simulate interactions among the stakeholders' involved to easily elicit the requirements [Hauge et al. 2014].
However, a weak point of current PSS design is validation. Indeed, it is usually faced at the end of the design process, on a preliminary functional prototype that merges product, services and the proper ICT infrastructure. Examples of validation methodologies in the PSS context are: PSS-Inspector, that is used mainly during design reviews [Suvarna et al. 2010]; adoption of the SSC4IPS² Service Self Checklist [Akasaka et al. 2013]; and the analysis of user-product interaction [Exner et al. 2013]. However, all such methods are applied on physical prototypes, once the final PSS prototype is realized, and focused on technical and technological aspects. Only the third one can be applied also at a conceptual level on static prototypes, but only PSS features can be analysed without simulating the PSS behaviors and reactions into final users. As a consequence, such techiques can support an early validation but do not solve the main problems of late re-design and numerous process interaction. In fact, optimization guidelines come up at the end of the desing process and, when a PSS features have to be modified, the entire process must be followed coming back to the design stages. In this direction, an interesting example of innovation is represented by a recent research that proposed to use Virtual Reality (VR) technologies to create a Smart Hybrid Prototype (SHP) able to integrate physical prototypes with digital models into a virtual environment to enable a direct experiencing of PSS during the design stages [Exner and Stark 2015]. However, they proposed only a validation framework to collect experimental responses after PSS design, without involving users in an effective PSS validation and re-design.

2.2 User-centred design for PSS

User-centered design (UCD) is a design philosophy that aims to extensively addresses needs, demands and expectations of users at each stage of the design process. A traditional UCD process starts from the identification of users' needs and establishment of requirements, and proceeds with the development of alternative design solutions to meet such needs, the building of interactive prototypes which can be assessed, and finally the evaluation of what is being built by involving final users [ISO 13407:1999 1999]. In this context, ergonomics and usability historically assumed a central role and are clled as Human Factors (HF) [ISO 9241-210:2009 2009]. HF refers to both pragmatic attributes (functionality, dimensional aspects, safety, performances) and user's wellbeing and satisfaction (emotional reactions, level of comfort perceived, sensations felt) [Norman 2004]. The combination of this two aspects has been defined as User Experience (UX).
In the context of PSS the investigation of UX is not common yet. On one hand, there is a lack of literature about the adoption of UCD approaches to PSS design. On the other hand, in order to investigate such response by UCD application, interactive prototypes able to support a proper behavioural and cognitive evaluation in shorter time are needed [Bullinger et al. 2010], but creating a realistic prototype for PSS is hard to realize. In fact, it requires a functional and interactive prototype able to reproduce the integrated functioning of both product and services with high fidelity in order to reproduce both physical and cognitive responses in the final users. These aspects are strongly interrelated and difficult to divide, so that the UX of a PSS is a mix of behavioral feedback, which refers to the way in which users behave in front of the PSS and how they act and reach, and cognitive feedback, which refers to the judgment that user makes about the PSS as a whole, on the basis of the information perceived through the sensorial modalities and experiences lived. As far as PSS, traditional low-fidelity prototyping techniques (e.g. paper sketches, cardboard mock-up) can be applied only for some aspects of product or service interfaces, such as the layout of controls and displays [Hall 2001], but they are not suitable for the evaluation of the effects of visual, motion, tactile, and auditory feedback, that usually a PSS has. In this

context, high-fidelity prototypes (e.g software and physical mock-up) can make users realistically appraise product aesthetic attributes and functionalities [Sauer and Sonderegger 2009], but they are costly and are usually built up in an advanced design stages, when the majority of features are already defined.

In this context, Virtual Reality (VR) technologies have been demonstrated to successfully create virtual interactive mock-ups within immersive environments to simulate product functions; furthermore, using virtual mock-ups allows to rapidly carry out usability testing from the earliest design stages involving users substituting costly physical mock-ups [Park et al. 2008]. The level of interaction can be improved mainly thanks mixed prototypes and virtual interactive mock-ups. The former combined physical objects with virtual objects, but integration is usually hard due to the complexity of systems' interfaces, the unnatural manipulation, the non-intuitiveness and intrusiveness of the adopted devices, especially for non-expert users. The latter is based on virtual interactive virtual prototypes (IVP) and allows the user to interact with the prototype into an immersive environment in a more natural way, creating a realistic interaction [Bordegoni and Ferrise 2013]. IVP has been recently adopted to evaluate ergonomics and user experiences on products in numerous cases and different industrial sectors (from household appliances to automotive, from interior design to furniture), but they are not applied for services.

3. User-centred design for PSS

3.1 Research approach

The research proposes a user-centred methodology to involve the users into the definition of the PSS features and early validation during the design stage. Firstly, users are involved by the adoption of UCD techniques (such as interview, questionnaires and role-playing): in particular, role-playing highlights the PSS users' needs and tasks to be created to satisfy them by directly considering a set of "personas" representing sample users [Simsarian 2003]. Role-playing is performed by experts in the specific PSS domain, who play as characters into the real context of use simulating the actions and moods of the consumers. Personas are wider used in the investigation of user experience as fictional characters representing different user types and experiences. The following step is the technical analysis of PSS tasks in order to define the PSS functions. In this context, Business Use Case (BUC) analysis provides a user-centred investigation and defines a PSS model where the most significant items are schematically represented and the goal-oriented interactions between external actors and the PSS are depicted. In this way, it supports the definition of the stakeholders involved and the main PSS features, the key business features, the necessary sub-systems, and the infrastructure capabilities [Wallin et al. 2013]. Finally, PSS validation is based on the creation of hybrid PSS digitial mock-ups, able to concretize the PSS features and to simulate the human-system interaction to support UX evaluation into an immersive virtual environment. Such mock-ups combine an high realistic visualization (e.g. high quality aesthetic rendering, realistic environments, truthful use cases) with a high level of interaction and simulation of the PSS behaviours according to pre-defined models (e.g. movements of product parts according to some interaction with its interface or the service funcitons, real-time feedback connected to the service delivery): in order to do this, the Hardware-in-the-Loop (HIL) approach [Harrisons et al. 2012] is adopted to create hybrid functional protoyopes which combine the virtual representation of the system with its effective behaviour by adding a mathematical representation of all related dynamic systems. The next section described the structured methodology that allows to implement such an approach.

3.2 UCD methodology for PSS

The proposed methodology starts from the analysis of the user' needs and proceeds with an iterative evaluation of the UX on PSS virtual mock-ups. The logical flow of the proposed methodology is explained in Figure 1 and consists of six main steps:

1. Analysis of the users' needs: thanks to UCD techniques (i.e. focus groups, questionnaires and interviews), the targert users' needs and customer requirements are identified. Firstly, a set of personas are defined by identifing target users' profiles and habits, as well as the most common use scenarios and a set of use cases related to the specific PSS. Subsequently, according to role-playing, experts play as characters to implement the specific use cases. As a results, the main

users' needs are elicited. Finally needs are weighted according to their frequency and importance, according ot the experts' judgement;

2. Analysis of the PSS functions and scenarios: the PSS scenarios, as defined during the first step, are investigated by BUC technique and a set of diagrams representing the user-product-service interaction are depicted. In particular, BUC diagrams clearly define actors, items of both products and services they interact with, actions, and assets needed. In this way they easily support the definition of the PSS functions, expressed as verbs;
3. Definition of the PSS design features: user needs and PSS functions, obtained in the previous steps, are mapped into a correlation matrix by adopting Quality Functional Deployment (QFD). Correlation, espressed by a 0-1-3-9 scale (where 0 is no correlation, 1 is poor correlation, 3 is medium correlation, and 9 is high correlation), indicates how much each function satisfies each need. Values are defined by experts on the basis of their own experience, experience done during role-playing, and users' investigation by interviews and direct observation in real contexts of use. As a result, functions are weighted according to the correlation to their needs and needs' weights, and their analysis allows to define the PSS features, which correspond to those product and service properties needed to ralize the most relevant functions;
4. PSS modelling: once PSS features are defined, a preliminary concept of PSS is designed by Computer-Aided tools. For instance, Computer-Aided Design (CAD) systems are used to create the 3D models of products and product interface, Computer-Aided Styling (CAS) are used to create the realistic rendering of both product and environments to create the different scenarios of use, while Computer-Aided Graphics (CAG) are used to model the service interface and its behaviours. Different tools can be used for these purposes according to the company practices;
5. Creation of a Interactive Digital Mock-Up (IDMU): an integrated prototype able to simulate the PSS behaviours is created thanks to the integration among the models developed in the previous step and the creation of the PSS behaviours according to HIL approach. Different software tools can be used to create an interactive model, depending on the specific type of product (i.e. automatic machine, household appliances, ect.) since they are strictly related with the real control platform;
6. Evaluation of PSS UX in immersive virtual environment: the IDMU built in the previous step is projected into an immersive virtual environment where users can experience the PSS interaction and UX can be assessed by a proper evaluation protocol. Different set-up can be created: however, the virtual environment should be equipped with stereo visual facilities able to create a 1:1 scale prototype, tracking capabilities to make the user the protagonist of the scene, and interactive devices to provide a real time interaction with the PSS features and behaviours. UX can be assessed by a proper evaluation protocol considering both behavioural and cognitive responses according to the international regulations about ergonomics and the more recent UX theories. It depends on the specific context of application and PSS typology, so it needs to be defined case by case.

Figure 1 describes the steps of the proposed methodology and how the different actors are involved (both people from different company departments and users) at each step. In particular, it clarifies how users are involved both at the beginning and at the end of the design process.

The contribution of the proposed methodology can be summarized in the following points:

- early testing of integration between the product and service components,
- evaluation of the user experience during the early design stages,
- involvement of sample users during preliminary testing of PSS,
- simulation of numerous design alternatives and PSS scenarios at low cost.
- Such factors will finally bring to shorter time-to-marker, a sensible reduction of late design changes and prototypes, and higher saetifaction of the users' needs and brief requirements. It is worth to notice that proposed methods is general purpose and has been defined independently from the specific PSS and industrial sector.

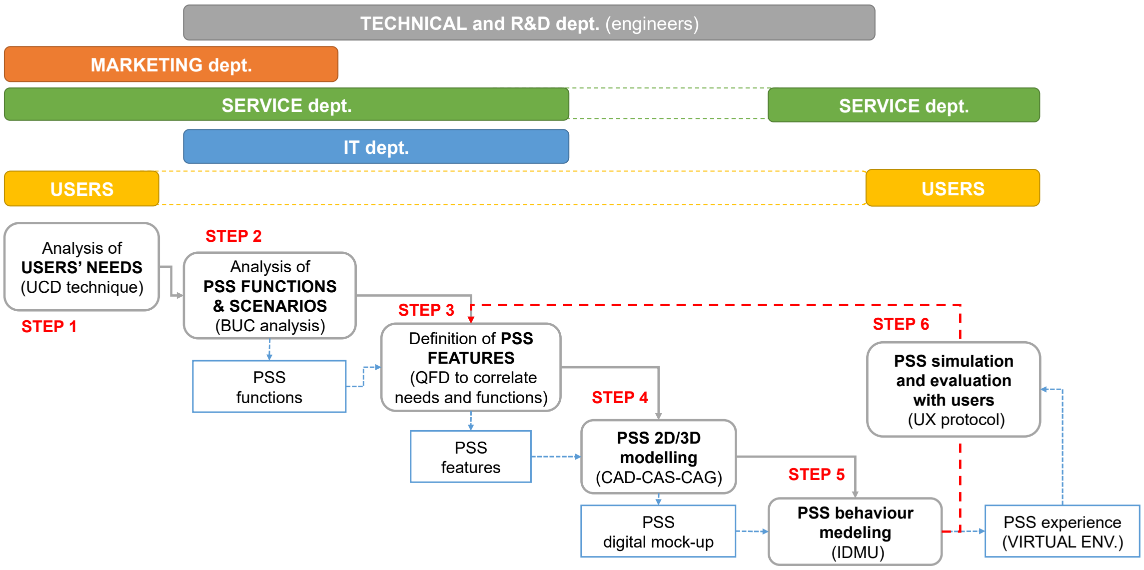

Figure 1. UCD methodology to design PSS based on UX

4. Case study

The case study presents a possible application of the proposed methodology to an industrial sector. In particular, it starts from the experience of an Italian manufacturing company that designs and produces household appliances, which recently faced the Servitization challenge.

The company is moving from designing traditional products to designing integrated product-service solutions, with the aim to evolve its business portfolio, increase its market share and create new business opportunities. In particular, household appliaces are very good candidates to be ehnanced with services due to the following factors: 1) they usually support a lot of common activities within a domestic environment (i.e. washing dirty clothes, drying, cooking and freezing food, etc.), 2) they are characterized by strong human interaction, 3) they usually carry out a "function" more than being a product, so the most important thing is not their ownership but the service offered, 4) they are recently equipped with sensors, smart components and ICT systems (mainly to guarantee technical assistance and report back of problems) so they can easily retrieve data also for services, and finally 5) they have advanced user interfaces. These facts facilitated the introduction of services as an add-on of traditional products.

In particular, three years ago such a company also joined an European project to promote the shift from products to PSSs into a structured manner (i.e. MSEE project, http://www.msee-ip.eu). The project supported the company to better understand the servitization process and to organize its resources in order to create a PSS [Peruzzini and Marilungo 2014]. The new PSS idea to be realised focused on washing machines (WMs) and consisted of the creation of a set of supporting services for simplying the use and management of the actual products. Especially, the PSS idea combined product monitoring functions with washing-supporting features and maintenance-related aspects: product monitoring consisted of energy consumption and product behaviors (e.g. programs, temperature control, water and soap control, etc.), washing-supporting features consisted of providing best practices to improve the product use as a sort of mentoring service, and maintenance-related features concerned the detection of dangerous situations and remote maintenance capabilities. Data were monitored by specific sensors and collected in a dedicated database; a set of elaboration algorithms analysed data to recognize the specific use scenario and support the user with personalized and tailored suggestions and advices. A web/mobile application provided personalized messages directly on their mobile phones. In the following paragraphs the traditional PSS design process and the new UCD methodology are presented for the industrial use case.

4.1 Traditional PSS design

In order to realize this idea, the company designed separately a new smart appliance (physical product) able to be connected with the company central system through a proper ICT infrastructure (system) that delivered the above-mentioned services to customers (i.e. smart maintenance, best practices, appliance monitoring). PSS was designed in a traditional manner by adopting product-centric supporting tools, and it was tested with users only at the end of the process on a pilot series.

The PSS design followed a P-SLM process according to the model proposed by Peruzzini et al. [2014]. During Product-Service ideation, ideas were examined by means of brainstorming involving people from different company departments (i.e. marketing, IT, service, R&D) and also external actors (i.e. designers, suppliers). At the end, the most promising ideas were selected and, for each of them, a deep requirement analysis was conducted in order to identify the main PSS requirements (e.g. technical, aesthetics, etc.). Secondly, Product and Service design occurred separately in a parallel way. They dealt with technical modelling, that allowed identifying respectively the product functions and the service functionalities to be delivered. Such a model supported the identification of tangible and intangible assets. Furthermore, the business configuration was conducted according to the Canvas model and main actors and information flows were defined. Subsequentely, Product-Service integration focused on the definition and development of a proper ICT supporting infrastructure to realize the integration between the physical product and the intangible services to be delivered. After that, the first PSS prototype was realized and a first feasability study was carried out in order to model the PSS revenues and the pay-back period. A pilot series was created (50 units) and proptypes were installed at users' home for validation, considering sustainability assessment and user satisfaction. However, such a workflow highlighted a set of criticalities linked to the late validation of the PSS design: indeed, validation and users' judgements and performances were collected only during usability test on final prototypes. Numerous changes were required to the product and to the service interface and functions, so that late design changes were applied with a significant increasing of time and cost. This fact caused a longer time-to-market and a higher quantity of resources spent (economic and human) than expected.

4.2 User-centred PSS design: A new perspective

The proposed UCD methodology was adopted to the same use case after the project end, in order to understand if you could bring some advantages in respect witht the past experience. Another design team was created, whose people did not experienced the previous case so they were not aware about the previous design process, and the same PSS was designed. The new design process followed the six phases as presented in section 3.2. In particular, the new flow of activities is shown in Figure 2. It describes how the PSS design stages have been developed by introducing UCD techniques and design reviews (DRs) on virtual mock-ups. In particular, people from the Marketing department involved in the new design team analysed the users' needs by applying the UCD techniques. Indeed, they organised focus groups according to the different user segments identified, and they used questionnaires to collect information by users. After that, they use role-playing to simulate sample users' behaviours and reactions. Results from such an activity is shown in Table 1 and Table 2. Subsequentely, the new design team investigated PSS scenarios by adopting BUC analysis in order to identify the main PSS functions. An example is reported in Figure 2. Furthermore, technical and IT people, as well as people from the Service department, worked to identify the main PSS features by QFD matrix; Table 3 shows an example done during the case study, where the columns contain the PSS functions identified in step 2, and the rows contain the users' needs (as defined and weighted in step 1). Their correlation allowed designers defining the PSS features able to ralize the most relevant functions, and to be modelled by Computer-Aided tools. For the PSS feature modelling, the design team used different tools: CATIA (by Dessault Systemes) 3D CAD system to realize the 3D of the physical product, VRED (by Autodesk) to model the service interface and its behaviour, Photoshop (by Adobe) for interface configuration, and Silverlight (by Microfsoft) as a service interface simulator.

Table 1. Users' needs collected applying the UCD techniques

Categories	Needs
Washing Machine (WM) monitoring and control	- Have feedback on the current state of washing machine - Have information about the last washing cycle - Have statistical analysis of the past cycles - Activation of the washing machine by remote systems (e.g. smartphone, PDA, tablet, etc.) - Have feedback about alarms and cycle failure
Flexible assistance service	- Select a tailored maintenance contract, according to user usage - Have remote maintenance actions and assistance - Have information about planned and scheduled maintenance actions - Have the possibility to order spare parts for the scheduled maintenance operation and delivery at home
Disposal & recycling service	- Have automatic and free disposal and recycling - Have a free contract or a little revenue for the machine disposal/reclying
Automatic soap/cleaner recharge	- Have information about the soap level in the vessel of washing machine - Have a feedback in remote systems (e.g. smartphones, tablets, pc, etc.) about the need of recharge - Have the possibility to automatic re-order or purchase (i.e. by web portal) new soap recharge - Have information about marketing proposals (e.g. offer, 3x2, new specific soaps, on-line flyer, etc.)
Health & safety service	- Have a safe home - Monitor people at home and their status - Automatic emergency actions

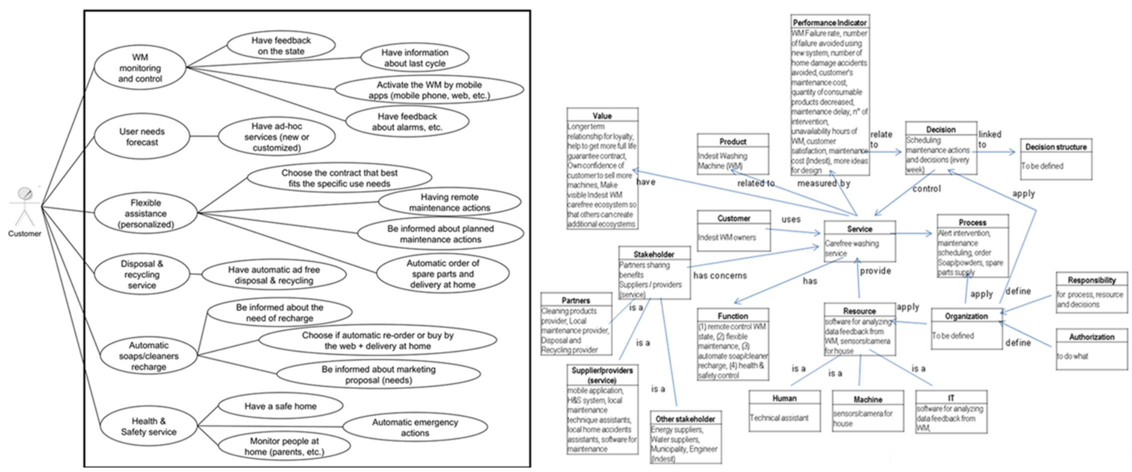

Figure 2. Application of the BUC analysis for the case study

Table 2. QFD analysis according to the results of step 1 and 2

Categories	Weight	PSS functions: High machine performance	Energy efficiency	Other resources efficiency	Balance between quality & price	High quality of components	Easy to use	Safety and security	Function personalization	Reliability & Durability	Appliance control
WM monitoring & control	**3**	9	3	3	1	3	3	0	3	0	9
Flexible assistance service	**3**	3	0	3	3	9	3	0	9	9	1
Disposal & recycling service	**3**	1	0	1	9	3	0	0	0	3	0
Automatic soap/ cleaner recharge	**2**	3	3	9	1	0	9	1	1	0	9
Health & safety service	**1**	0	1	1	0	0	0	9	0	0	0
		45	**16**	**40**	**41**	**45**	**36**	**11**	**38**	**36**	**48**

At the this stage, VR technologyies allowed to project the virtual mock-ups into an immersive and interactive environment where the user and his/her behaviours are tracked by a tracking system, using the facilities of the Vip Lab (Virtual Prototyping Lab) of the Department of Engineering "Enzo Ferrari" at the University of Modena and Reggio Emilia. Contemporary, the service prototype was delivered on smart phones through a Silverlight application. The Lab is equipped with a set of advanced Virtual Reality technologies for immersive and interactive navigation, such as: a large CADWall (by Steward) for rear projection 5800x2000 mm; two high-performance Barco Galaxy projectors with 7,000 lumens for high-quality stereoscopic viewing; a VICON tracking system with nr. 8 BONITA B10 cameras; a Volfoni ActiveHub radio frequency emitter for active stereo glasses and active Volfoni Edge glasses; a VICON APEX interactive navigation device; a Denon AVR system with Dolby surround sound receiver. Finally, UX testing has been executed with sample users (10 users were involved): it allowed to verify the impact of PSS design choices on the users' response and to measure their appraisal by testing numerous alternatives (i.e. specific product features, service functionalities and related product feedbacks, flows of actions to be executed on the product and on the service interface). Figure 3 shows a user interacting with the PSS prototype during UX evaluation and the Vip Lab set-up.

A) B)

Figure 3. UX testing: Interaction with product prototype (A) and Vip Lab set-up (B)

The main differences in PSS design process using the new UCD methodology, in respect with the traditional PSS design approach, were analysed by Diary Study and Interaction analysis, as proposed by Peruzzini et al. [2011]. A set of heuristics were selected to identify the most important process indicators and a set of metrics were used to measure the design process quality during DRs. In particular, the design team members monitored all their activities by fulfilling Diary Study MSWord formats and by audio recording. Collected data included verbal description of design knowledge and nonverbal information (i.e. hand and body gestures, communication style, etc.). Such data was collcted for DRs in both traditional PSS design process and UCD PSS process. The authors analysed such data and assess the evaluation metrics for all the DRs in the process. Global results are synthetized in Table 3.
The main benefits achieved thanks to the UCD methodology can be inferred from the last column in Table 3. A sensible reduction in the global process time was due to less and more effective DRs, as well as the reduced number of design interations and physical prototypes. At the same time, the correspondence to the brief requirements and the higher user satisfaction highlighted how the new UCD method forced people to pay more attention to the users' needs and expectations from the preliminary ideation stages and also in the evaluation stages. Indeed, in the previous process, ideation was supported by brainstorming and the Marketing department defined the users' need; now ideation is more structured and suppoted by different tools (i.e. role-playing for needs' analysis, BUC for scenario definition, QFD for requirments elicitation, etc.) which guarantee a more user-centric needs' analysis. Furthermore, DRs are shorter and more effective since, with the new UCD method, most of them were executed within an immersive virtual enviroments using interactive mock-ups reproducing both products and service behaviours. Also testing on interaction mock-ups support early PSS optimization and late design changes are strongly reduced, with great time and cost saving.

Table 3. Comparison between traditiona PSS design and UCD PSS design (via Diary Study)

Evaluation heuristics	**Metrics**	Unit of meas.	**Traditional PSS design process**	**UCD PSS design process**	**UCD benefits**
Process quality	Design iteration	No.	7	2	-71%
	Design Review	No.	12	6	-50%
	Time-to-market	Months	8.5	5	-31%
Design Review quality	Design reviews duration (average)	Min.	120	90	-25%
	Physical prototypes (total)	No.	5	1	-80%
PSS quality	Brief requirements correspondance	%	60	85	+42%
	Customer needs' satisfaction	%	52	80	+54%

5. Conclusions

The present research defined a user-centred methodology to successfully design PSS taking into account humans factors. It integrates User-Centred Design (UCD) techniques in order to involve users from the early stages, and proposes to realise hybrid prototypes able to simulate the human-PSS interation. Indeed, numerous companies have actually acquired the technical and technological knowledge necessary to develop integrated product-service solutions, but PSS design is strongly technologicaly-driven and poor attention is usually paid to final users, and usually the final solution is not well appreviated by end-users and numerous late optimizations are necessary before the market launch. Users' appraisal is usually evaluated only at the end of the design process on physical prototypes, with an increase of time and costs. Indeed, a PSS is generally characterized by a great interaction with the users and, for its success, the satisfaction of users' needs and expectations is fundamental. In this context, the proposed methodology allows an early simulation and evaluation of PSS during the preliminary design stages by the involvement of sample users and the simulation of numerous design alternatives and PSS scenarios at low cost thanks to hybrid prototypes.

The research presented the application of the proposed method to an industrial case study, directly inspired to a manufacturing company involved in PSS design, which faced difficulties in its optimisation using traditional methods. The same PSS was re-designed using the proposed approach and the process was faster and achieved a higher UX evaluation. The two processes (i.e. traditional PSS design and UCD PSS design) were compared according to a set of heuristics and metrics; experimental results highlighted the benefits achieved thanks to the new method application. The method is a generic and can be adopted by different company actors/departments working to PSS design. The case study belonged to white goods sector, but it could be easily appled to any other manufacturing sector. Future works will focus on the definition of an ad-hoc protocol to evaluate UX on interactive virtual prototypes, and the adoption of also augmented reality technologies, such as Oculus Rift3 and Microsoft Halo4, to create a stronger immersive experience.

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