Defining the Potential of Extended Reality Tools for Implementing Co-creation of User Oriented Products and Systems

Sandhya Santhosh[1], Francesca De Crescenzio[1], Bonaventura Vitolo[2]
[1] University of Bologna, Forli, Italy
[2] Geven S.p.A, Naples, Italy
sandhya.santhosh2@unibo.it

Abstract. In the last two decades a huge number of interactive and collaborative applications of Virtual Environments for designing products has been proposed. Such applications have been recommended as tools to implement Human Centered Design Approach in experiments where potential users are involved in participatory design sessions before going for production. In this kind of experiments, we observe that users are mainly involved in the validation of solutions previously elaborated by designers while in the last decade the most innovative approach in the creation of solutions seems to be moving from a user centered design to a co-design or co-creation process. Thus, it is essential to have a platform where the elements of co-creation can be fulfilled in building a successful project. The purpose of this paper is to outline the concept of co-creation and the significance of co-creation platforms alongside of proposing innovative tools for building the co-creative environments. The paper aims to layout a classification of the Extended Reality (XR) tools currently available and of their functionality as valuable means to actually embed co-design and co-creation concepts in Virtual Environments evaluating the advantages that this can bring to Industry through field studies. A review of innovative solutions like Virtual, Augmented and Mixed reality technologies is examined and drawn towards the requirements of the concept through a literature research. Additionally, a co-creative environment for designing aircraft cabin interiors is conceived and discussed a with company representative.

Keywords: Co-creation, Extended Reality, Collaboration, Interaction platforms.

1 Introduction

In the recent times innovative organizations are shifting their ideation strategies towards the concept of "Co-Creation" in order to improve their creative businesses. Such process is based on the active involvement of final users or customers in the design process of products or services and can be implemented in whatsoever domain. In fact, according to Sanders and Stappers et al. there is no specific definition for co-creation and it can be adapted to the field it can be related and developed to [1]. With regards to new product, co-creation is believed to be the collaborative development of new value, the value being concepts, solutions, products, and services [2]. For product development, it is well known that early collaboration of various users is essential to

work towards a shared goal reducing the time taken in completing the task. To this aim, co-creation meetings can be challenging due to diverse participants, be it designers or non-designers [3].

In this context, it is essential to identify the technological tools that allow users to go beyond the validation of already designed products and to play an active role in generating ideas and directly building solutions. Such tools must be capable of providing the key elements in developing co-creation platforms which are: Collaboration, Interaction and Experience [4]. How and where to collaborate, how to interact and what will be the experience are the basic questions every user would have when the concept of co-creation is introduced in product development phase.

To this note, Extended Reality (XR) technology, a term referring to all real-and-virtual combined environments & a rapid growing field, is paving its way in to numerous grounds. Furthermore, XR serves as an umbrella term for Virtual, Augmented and Mixed Reality technologies (VR, AR and MR) offering high potential in generating solutions to common constraints as collaborating and interacting platforms [5]. There are very few studies actually correlating the co-creation process with the conception of VR, AR and MR platforms as tools to successfully implement the process. Nevertheless, recent advancements in Head Mounted Display's (HMD's), Goggles, CAVE and mobile technology lead us to believe that companies will be facilitated in the actual evolution towards the co-creative approach.

In this paper, we review the virtual platforms available for building co-creating environments and their suitability towards the concept alongside of the hardware available and previous works performed using XR tools.

2 The concept of Co-Creation and Importance of Co-Creation Platforms.

Co-creation is still an emerging concept and is usually linked to business activities with customer playing a crucial role from beginning to end in a product or service design process. Prahalad and Ramaswamy et al. illustrates co-creation as interaction between companies and customers in order to co-create value experience with product and to deliver a unique co-created value [6]. These experiences signify the quality of interactions and lead to positive relationship between the customer and the company. Two famous companies which adapted customer co-creation and co-creation in new product development are LEGO [7] and BMW Group's Co-Creation Lab [8] respectively.

Mandolfo et al. has elaborated co-creation variables affecting consumers and companies [9]. In a study by Hitachi on "Co-creating the Future" [10], 61% of respondents have mentioned that adopting co-creative approach in their businesses to innovation has reduced the cost of developing products and services. Overall, co-creation is believed to bring together users and designers to work towards a shared goal. In fact, Prahalad et al. stated that introducing co-creation in to design practice will change the way we design and will also affect the tools and methods [6]. The study even relates co-designing and participatory design to co-creation [11].

The power of co-creation lies in to how well the users are collaborating and communicating in the environment [12]. Developing a co-creative environment or a platform has been unprecedented and has not been given much of importance till now. Designers, stakeholders, customers, engineers, suppliers, and other actors should interact on a common platform in order to adapt to the concept of co-creation and avoid misinterpretation and communication challenges. So, the experience they perceive also becomes a key factor in maintaining relationship and work collectively. Since co-creation can be regarded as a new way of practicing innovation within organizations in multiple fields of study, interactions and collaborative innovation experience factors play a vital role in the success of the concept. This recalls the need for social structures to support the quality of interactions in succeeding co-creation. A deeper definition to co-creation thus focuses on connections/interactions between people and collaboration rather than just involvement and creativity [13] [14].

An empirical study performed by Fuller et al. has highlighted the importance of co-creation experience and proves that it impacts user's quality of work [15]. Companies involved in co-creation bear the risk of less participants due to poorly managed collaboration platforms and consequently discouraging innovation process through valuable contributions. There are numerous existing technologies used as tools for co-creating environments. Most of them are driven to be web and network based to connect the users [16] such as: Crowdsourcing (a software or online platform with unrestricted access) and Netnography (webforms, vlogs, blogs etc.) [17]. A pattern which can be noted through these existing platforms is that collaboration and interaction between the users although happen in a same environment, user experience to the project is still limited.

With the growth of internet and innovative solutions towards communication technologies, there has been a lime light towards virtual platforms for developing co-creation environments. Kohler et al. explored virtual worlds for co-creation systems and highlights the importance of user experience to improve connections, creativity and thus co-creation [18]. It is not only bringing two or more users to perform an activity, but requires various types of interactions among the users, technological systems and environments.

Little research exists on how to design co-creation platforms for a user-centric experience and, to address this concern, we propose immersive environments for collaborating, interacting and user experience. Technologies such as Virtual, Augmented and Mixed Realities offer high potential to virtually collaborate, visualize and co-create in an imaginary unknown world. The following section will extend the types and definition to these technologies and explore the suitability towards the concept.

3 Potential Co-Creation XR platforms

Deep interactions with conversation and additional information introduces user to the product features that are more convincing. Thus, it is important to develop interaction-based platforms for co-creation environments. Extended Reality is such technology

which offer high promising challenges to collaborate, interact, visualize, co-create/co-design. The technology have evolved to use avatars to offer appearances, gestures, voice and ability to interact with others using virtual artifacts [19]. XR can go beyond reality, providing users with elements that are not possible in the real world. With these objectives in consideration, the following section will provide an overview of the technologies and what the world is up to in developing the elements of co-creation with XR.

3.1 Virtual Reality

Virtual Reality (VR) is a complete 3dimensional digital experience. Unlike traditional interfaces, VR places the user inside an experience without any realization and contact with real world [20]. Numerous VR technologies based on display systems have emerged enabling a user to experience the virtual world [21] such as: Passive Stereoscopic Theatre (PST), Cave Automatic Virtual Environment (CAVE) [22] , and finally, Head-Mounted Displays (HMD's) like HTC Vive and Oculus Rift.

Interacting with a virtual environment is the key constituent of many virtual world applications and co-creation. In order to improve the effectiveness of development projects, VR enabled-interactive objects are designed by Kostis and Ritala et al. to improve digital co-creation practices [23].

Interactions in the form of non-verbal communications (voice and gestural commands) have been successfully incorporated to VR environments. A set of hand-based tools such as wands, hand-controllers or other input devices such as goggles & gloves are used to manipulate virtual objects for the users to interact has been designed in developing collaboration in virtual reality [24].

A number of projects have been developed in VR which illustrate the elements of co-creation. For instance: *Coco Verse* is an immersive VR experience allowing interaction and collaboration for learning and creativity [25], an initial iterative design process in VR using Oculus Medium was developed by El-Jarn et al. for artists in order to collaborate with other creative leads on sketching slaying the 2D sketching step with a leap to 3D modelling [5], a unique social VR platform using HMD's like Oculus Rift has been explored by Saffo et al. for conducting user studies, *Facebook Spaces* is another VR app which allows interaction between friends using a VR device such as Oculus Rift and HTC Vive [27].

3.2 Augmented Reality

Augmented Reality (AR) unlike Virtual Reality isn't fully immersive, artificial experience. Instead, it adds digital information such as graphics, sound and video on top of an existing physical world. Augmented Reality can be implemented through various kinds of visualization devices such as Heads-up displays, Holographic displays, smart glasses and hand-held devices [28]. The excellent thing about AR is it does not always require dedicated hardware but also phones, tablets, computers can be utilized. With advent growth in technology, it can be predicted that phones, AR glasses and headsets will coexist in the future. Some of the popular AR HMDs are Microsoft

HoloLens, Magic Leap One & Google Glass. Collaboration in Augmented Reality can be designed to be either co-located or remote.

There are several examples in the last two decades of collaborative AR environments. *The Studierstube* is an AR project using HMD's and allows multiple users to examine similar data in the same room [29]. Another such example is the use of Microsoft HoloLens by NASA's Jet propulsion Laboratory allowing the scientists to work on their Mars rover missions [30]. *Spatial* is one another augmented reality conference application with shared experiences for multiple remote users using HMD's [31]. Mourtzis et al. developed AR collaboration for product design [32]. A complete remote collaboration has been designed by Zillner et al. in order to support the local helper by a remote expert [33]. Thus, interaction is considered smooth and easy in AR as it can be pre-designed across multiple devices.

3.3 Mixed Reality

Mixed Reality (MR) is an extension of Augmented Reality allowing real and virtual elements to interact in an environment. MR is capable to interact with and manipulate both physical and virtual items using next-generation sensing and imaging techniques. It provides the ability to have one foot (or hand) in the real world and the other in an imaginary place offering an experience that changes everything. It is also called as enhanced AR, as it is similar to AR but provides more physical interaction [34]. It requires an MR headset device such as Microsoft HoloLens or Magic Leap One.

Collaborative experiences in MR utilizes gestural and speech recognitions allowing multi user interaction between virtual and physical environment. There are many systems designed for this purpose. *SharedSphere* is one such system developed by Lee et al. allowing remote collaboration using See-through HMD, Epson BT-200 equipped with a camera and sharing captured video with remote user using a VR HMD, HTC Vive [35]. Bait et al. uses a similar strategy but captures live 3D panorama using a sensor cluster installed in the room. With the combination of gaze and gesture cues, the system has been proven to provide a stronger feeling of co-presence for both users [36]. *CoVar* is a platform supporting VR and MR technologies developed by Piumsomboon et al. where users can collaborate with same local real-world environment or remotely [37]. A recent illustration of *Microsoft Mesh* has broken all barriers demonstrating MR platform to be delivering collaborative experiences [38]. The application has been tried by the laboratory and affirms the presence and shared experiences from anywhere.

A wide variety of technologies are available which can be integrated with the existing techniques to make collaboration a future possibility. Some of the main aspects for building a user-centric successful co-creation and the suitability of the mentioned tools have been studied in the following section.

4 XR and its suitability to Co-creation

The potential for XR platforms has highly altered the way to work, collaborate and interact. As specified above, the technologies have adopted to collaborate, visualize,

co-design or co-create providing experiences that had never been achieved before. However, the ability of these tool characteristics for building co-creative platforms anyways need to be verified whenever a co-creative session involving multi-users is built. Studies highlighting user experience to co-create in virtual world have concluded that with right approach, virtual worlds improve innovation, engagement, and co-creation [39]. These have been mapped in a traditional L-matrix diagram for easier understanding. The level of the XR equipment to cover the co-creation requirements is recorded as High (H), Medium (M) and Low (L) and the resulting matrix is as shown below.

EXTENDED REALITY		CAVE	Immersive HMD	See-through HMD	Hand/Held Display
	MR				
	AR				
	VR				
CO CREATION PLATFORM REQUIREMENTS	Collaboration [1] [2]	H	M	H	L
	Interaction [2] [4]	M	H	H	L
	Co-Presence [20] [30]	M	L	H	L
	Co-Located [23]	H	L	H	L
	Remote Sharing [5]	L	M	M	L
	Situational Awareness [26]	L	L	H	M
	Portability	L	M	H	H
	Intrusiveness	H	L	H	H
	Collaborative Digital content generation [18] [21]	M	H	H	L

Fig. 1. How does the XR platform cover the co-creation requirement? H: High; M: Medium; L: Low.

The simple matrix diagram visualized as in Fig. 1 is linked to the literature review and the study of innovation platforms. Besides the key elements necessary for building a successful co-creative platform, a number of other factors have been taken into consideration based on the studies and the aspects the tools offer. Co-creation has to be organized, managed and facilitated and it usually involves users from different passions and interests. Considering the on-going pandemic situation, apart from face-to-face collaboration, remote collaboration is regarded as high priority and thus the tools are also marked with consideration of remotely working capabilities.

5 Field study – A co-creative XR environment for designing aircraft cabin interiors

From the previous section it can be observed that see-through HMD's can enhance the co-presence features of a XR platform. In order to provide an example of a co-creative shared space we outline an application in the aircraft cabin interiors design evaluation field. The idea is emerged from the work done by authors in the framework of a Horizon 2020 project, the CASTLE (CAbin Systems design Toward passenger welLbEing). In CASTLE, a Human Centered Design approach has been followed for the validation of

design solutions through Human in the Loop Experiments performed in the CAVE and Head Mounted Displays (HoloLens1). These experiments aim at validating design solutions through the involvement of voluntary participants representing potential users [40] [41]. Several aspects of comfort, such as visual comfort, interaction comfort or living space comfort have been measured and used to iteratively validate design solutions. During such tests, each participant has been asked to experience the cabin interiors scenario and eventually to interact with it as a single user, representing, depending on the scenario to be validated, a potential passenger or a potential crew member. However, in a real aircraft several users are involved with different roles in the same scenario and they usually interact at the same time with the cabin environment.

For instance, in view of a Flight Attendant Seat (FAS) validation of a regional aircraft in a CAVE, two users enacting the roles of passenger and crew member cannot share the same environment mutually facing each other as in a real aircraft due to the fact that in the CAVE multiple users can share similar views and the virtual camera can have only a single point of view which is usually the point of view of one of the users, if tracked. Therefore, CAVE users obliged to stay on the same side of the screen limiting the front and rear view of the aircraft concurrently. Instead, using Head Mounted Displays multiple users can share the same virtual environment with independent point of views. The presence of another user can be developed to be physically visible in the same environment as a virtual avatar. With the aim of solving this issue we have conceived the co-creative XR environment interface based on the co-location of two different users, with two different roles, facing each other and living the same Virtual Environment wearing two synchronized See-Through HMDs (Microsoft HoloLens2). This scheme allows to have a shared and co-locating experience with an independent point of view in a virtual aircraft environment (Fig. 2). The design can also be extended to bring remotely located multiple users in to same virtual environment to interact and collaborate to work towards a shared goal.

Currently, the application is under technical refinement. Simultaneously, the authors are working at the tuning of the simulation scenario and of the validation procedure.

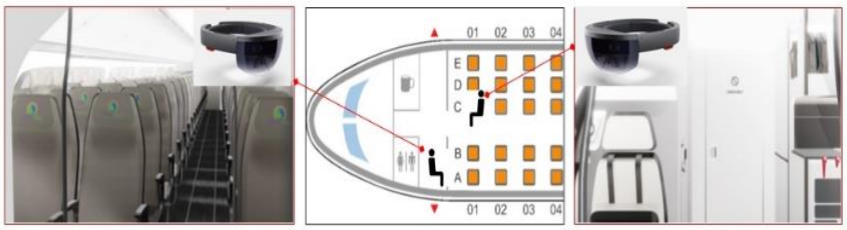

Fig. 2. Layout for multiple HoloLens users in cabin interior virtual environment. a) view form the crew seat; b) layout; c) view from the passenger's seat.

Furthermore, a reputed organizations manufacturer has been consulted to collect a practical point of view in the conception of multi-user co-located virtual environment in co-creative design validation and product development using XR tools. The manufacturer's industrial knowhow has provided an insight to extend similar environment to other figures of a company such as a designer (producing cabin interior

and cabin configuration) and certification engineer (who provides the main requirements) along with positive expectations of the results.

6 Conclusions and Future Work

This conceptual paper is an attempt to provide an insight to the idea of co-creation and explore the innovative tools and technologies available to build a successful co-creation platform. Whilst, co-creation is being evoked in every industry other than business world, it needs to be further investigated to be understood and applied correctly. Many works have been performed highlighting the importance of the user's perspective in a co-creative environment, but no prominence has been provided towards developing an innovative platform for practicing the approach. Thus, this paper provided potential innovative solutions like Virtual Reality, Augmented Reality and Mixed Reality as means to collaborate, to interact and to make true the experience for a user in a co-creative environment. We have listed out existing works with a literature review and have drawn a level-based matrix on to what level the XR platform/device cover the co-creation requirements.

A wide range of industries are showing interest in these new technologies and using the XR tools for co-creation will have a huge impact on them. The future works can investigate the development of co-creation concept with the tools mentioned for any kind of testcases to practically prove the potential of XR tools in building co-creation. Finally, a field study scenario has been presented in the aeronautics domain. Such scenario is being studied in the framework of CASTLE European project further to demonstrate the use of XR tools to co-create in industry.

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