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Mapping XR Platforms: Analyzing Immersion from the Designer's Perspective

Meng Li[1,2](✉), Daniel Houwing[2], Armagan Albayrak[2], Mohammad Shidujaman[3], and Daan van Eijk[2]

[1] Mechanical Engineering School, Xi'an Jiaotong University, Xianning Road 28, Xi'an 710049, People's Republic of China
limeng.81@mail.xjtu.edu.cn
[2] Faculty of Industrial Design Engineering, Delft University of Technology, Landbergstraat 15, 2628 CE Delft, Netherlands
[3] Department of Computer Science and Engineering, Independent University, 16 Aftab Uddin Ahmed Rd, Dhaka 1229, Bangladesh
shantothusets@iub.edu.bd

Abstract. Understanding humans are the key to developing optimal design solutions for product-service systems. In this sense, the experiential approach is in line but might go beyond typical Human Centered Design (HCD) methods in that it focuses on generating positive experiences that contribute directly to human well-being. Extended Reality (XR) showed the potential to replicate or simulate experience as a whole and gained attention from design communities. XR platforms confused design practitioners due to their fast-advancing amounts and relevant experiences. Hence, this study introduced two surveys on XR platforms to clarify which experiences they could provide and when to implement them into HCD processes. Survey 1 categorized XR platforms according to their key attributes and mapped them into the Experience Matrix. Survey 2 invented two designer personas and a fictional project to analyze barriers and strategies to implement XR platforms into design processes. Eighty-eight XR platforms were categorized into nineteen clusters, where *creation* and *simulation* had the highest numbers. Regarding implementing XR in design practices, the cost is still the key concern and there's a trade-off between software cost and assets purchased for different types of designers.

Keywords: XR platforms · Immersion · Experience Design · Design Tools

1 Introduction

Understanding humans have been acknowledged as superior in creating better design solutions for product-service systems [1]. On one hand, designers use many methods and tools to understand human needs and requirements, particularly Human-Centered Design (HCD) methods [2]. On the other hand, HCD methods often focus on specific design elements instead of the entire episode of the human-system interaction. Most of the HCD models thus articulate more or less pragmatic and technology-focused design

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qualities, which can remove barriers to fulfilling human needs instead of targeting the positive experience itself. Experiential approaches are in line with but beyond typical HCD models (e.g., usability) as they generate positive experiences to contribute to human well-being. Extended Reality (XR) showed the potential to replicate or simulate the entire experience of product-service systems [3], thus gaining attention from design communities. However, the fast-growing XR platforms and their experiences confuse design practitioners and barrier their implementation. This study hence introduces two surveys to explore: (1) XR platforms and relevant experiences and (2) XR platforms and their suitable design phases.

Survey 1 aims at categorizing and mapping the authoring platforms of XR experiences. It will first investigate the state-of-the-art authoring platforms that can generate immersive experiences. These XR platforms then will be categorized according to their key characteristics. The categories of XR platforms are mapped with an experiential model to indicate the types of experiences these platforms might create.

The goal of Survey 2 is to link the XR platforms to an HCD process. To analyze the strategies in XR platforms' choices, the authors first invented two personas of designers with a fictional design project. A collection of XR platforms from the previous survey is made for these personas to complete the design project. Each XR platform is assigned to the process of an HCD model to support design methods or tools. In the end, the authors will discuss the strategies for implementing XR platforms.

2 Related Work

2.1 XR: A New Opportunity to Develop the User Experience in Product-Service Systems

Extended Reality (XR) as the key technological setting to generate immersive experiences, is more and more applied in the domains of interior design, architecture, product development, simulation, training, and education. The first-person immersion generated by XR platforms could enhance key components in creative and intuitive processes, like emotional engagement and multisensory solicitation [4]. Additionally, XR supports true-to-life simulations, which are as effective as corresponding experiences in the real world [5]. Studies have demonstrated the effectiveness of XR platforms for designing airport interiors [6], evaluating the ergonomics of machinery [7], as well as creative form-making in visual art [8]. Hence, a consensus in design communities is forming about the new opportunities XR platforms might bring, particularly for experience design [9]. Exploring XR in experience-driven design has been accelerated by the uncertainties of global crises like COVID-19 during the last two years [10].

2.2 The Problems of Designers to Introduce XR in Design Practices

Though technological advancement enables XR platforms to craft experiences with high fidelity, design professionals are unfamiliar with these platforms and thus do not clearly know what to expect. This induces a problem. Pilot studies revealed both enablers and barriers of XR platforms in product-service system design. Considering the different functionalities and pipelines of XR platforms, they may add value to several design stages and tasks but might be incompetent for the others in terms of time and cost. For example, Rieuf et al. investigated how XR augment the quality of design outcomes at the early design stages and found out that the XR experiences effectively enhance design qualities [11]. Kim et al. showed the advantages of XR simulation to enhance the aesthetics and originality of the final design [9]. When introducing XR during the development, it became however troublesome. For example, modelling is less intuitive and even more frustrating in VR than on the desktop [12]. The authors interviewed industry team leaders and showed that generative tasks (like modelling) seemed more difficult in XR than ideating tasks like brainstorming and sketching. Some design professionals who are keen to integrate XR into design practices felt frustrated, even if they used XR for sketching instead of modelling.

Without a clear overview, designers can hardly decide where and when it is necessary or beneficial to implement XR, resulting in skepticism and a low application rate [13]. It thus needs to be researched for which design stage XR brings opportunities and for which design challenges XR is not yet ready. By observing the curiosity and the struggles of design teams when applying XR, the authors hence find it necessary to analyze experiences from current XR platforms from the perspective of designers. The goal of this study is to realize an overview of XR platforms in terms of the categories of experiences and the HCD process, as well as recommendations for different designers. This overview surveys: (1) how XR platforms can be categorized according to their experiences in an experiential model, and (2) at which stages of HCD processes can different XR platforms be useful.

3 Surveys

3.1 Survey 1 – The Categories of XR Platforms Based on Their Experiences a Subsection Sample

Method

Selecting XR Platforms

The website, *XRcollaboration.com*[1], is a well-known, open dictionary to register the latest XR platforms, including development toolkits, digital galleries, or virtual campus/conferences both from big companies and start-ups. The XR platforms enrolled in this platform were the main source of this survey. These XR platforms are documented via a structured one-pager on the website. The authors collected the documents of seventy-one systems listed in the dictionary up to January 2022, whereas two systems are excluded because they are merely concepts, or their XR-relevant functions were too limited, such as a hidden VR plugin. Nineteen XR platforms from the interviews with team leaders were added when they were not listed but were well-known in the design community. Subsequently, eighty-eight systems are included in the analysis.

[1] https://xrcollaboration.com/directory/.

Defining Key Categories
To analyze the XR platforms concerning the categories of experiences, the first step is collecting their key attributes of them. At first, the one-pagers of each XR platform were reviewed and corresponding characteristics were collected in a spreadsheet following the six filters on the dictionary: *max. Collaborators and speculators*, *hardware support* (i.e., XR headsets), *collaboration types*, *OS platforms*, *features*, and *industry*. The one-sentence description of each platform from the one-pagers was recorded as well. The authors independently labelled each platform based on its description, collaboration types, and features. When the information of a platform from the dictionary is not sufficient to put a label, the authors searched for external sources (e.g., video demos) from its official website. Labelling XR platforms requires an iterative process. For example, there can be a lot of similarities between a platform tagged as ‘Conference Room’ and another one tagged as ‘Roam & Discover’. After the first round of labelling, the authors put platforms with similar tags side-by-side and identified the differences: the platforms that have conference rooms but allow visitors to walk out and roam into a bigger world belong to the *Roam & Discover*, whereas the *Conference Room* is restricted to allowing a single meeting room. Thus, when the authors checked the key attributes to label the categories, they kept in mind that if the category seems to be ambiguous, look at similar categories. The final categories are labelled in such a way that they best describe the attributes of the category (shown in Fig. 1).

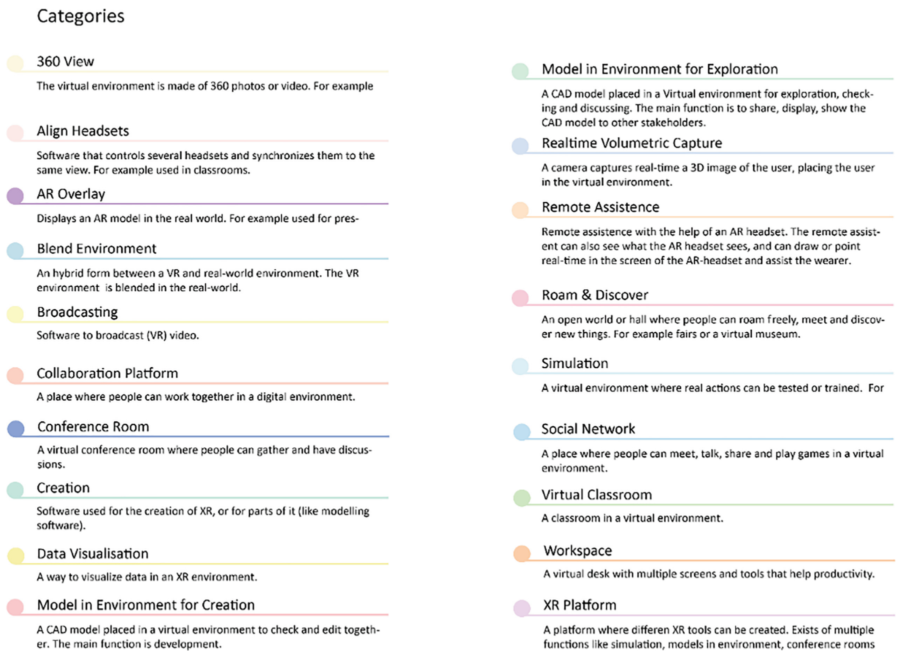

Fig. 1. The key categories of XR platforms

In the end, nineteen categories with specific names and synopses are identified and the numbers of XR platforms in each category were calculated. Each category is coded with different colors for the statistical analysis.

Mapping XR Platforms on the Experience Matrix
The authors applied the *Experience Matrix* by Pine and Gilmore to show the types of experiences that can be authorized via these XR platforms [14]. As a key step in the *Immersion Cycle* model, this well-known model (Fig. 2) explains the dimensions to engage the receiver of an experience [3]. The XR platforms are mapped into the four quadrants regarding the 'participation' and 'connection' dimensions. On the participation dimension (X-axis), the authors chose *supported hardware* (e.g., stereoscopic headsets) and *OS platforms* (e.g., smartphones or Web XR) to analyze whether an XR platform provides an absorptive or immersive experience; on the connection dimension (Y-axis), the authors selected *collaboration types* (e.g., co-working or lecture) and *features* (e.g., CAD images or 360 images) to analyze that an XR platform can support active or passive interactions.

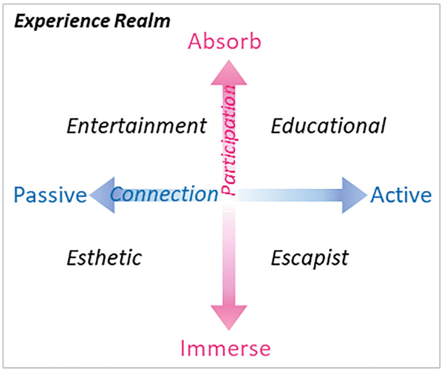

Fig. 2. The Experience Matrix with the 'participation' dimension (from **absorb** to **immerse**) and the 'connection' dimension (from **passive** to **active**) [14].

Results

The Categories of XR Experiences
In Survey 1, nineteen categories of the eighty-eight XR platforms were identified (Fig. 3). 'Creation', 'Simulation', 'MiE Exploration' and 'Remote Assistance' represent 46.6% of the key attributes, followed by the group containing 'Conference Room', 'Model in Environment for Creation', 'Data Visualization', 'Roam & Discover', and 'XR Platform'. These nine categories in total cover 82.9% of the key attributes in XR platforms.

Creation, the largest cluster, represents the functions to create content that can be used in XR. The *Simulation* group is about a virtual environment where one can integrate advanced interaction with a model. If we mainly look at the models to evaluate and explore in a virtual environment, then we get at the *Model in Environment for Exploration. Remote Assistance* seems like a popular way to use XR as well. The main goal is to help a remote expert in assisting a worker on location. For example, drawing in an AR application with motion tracking enables the drawing to remain on the object, and not move with the camera.

The *Conference Room* often provide a virtual space for co-working, meeting, and interpersonal interaction which can be accessed via multiple ends, such as XR goggles, tablets or smartphones. The *MiE Creation* is an extension of *MiE Exploration* where objects can also be edited. The *Data Visualization* category allows teams to visualize, manipulate and analyze data remotely and collectively. *Roam & Discover* is an open space where guests can roam freely, supporting collaboration, marketing, or showcases. The *XR Platform* are often a software development kit to create XR experiences focusing on specific fields, such as enterprise training, product visualization, or team collaboration.

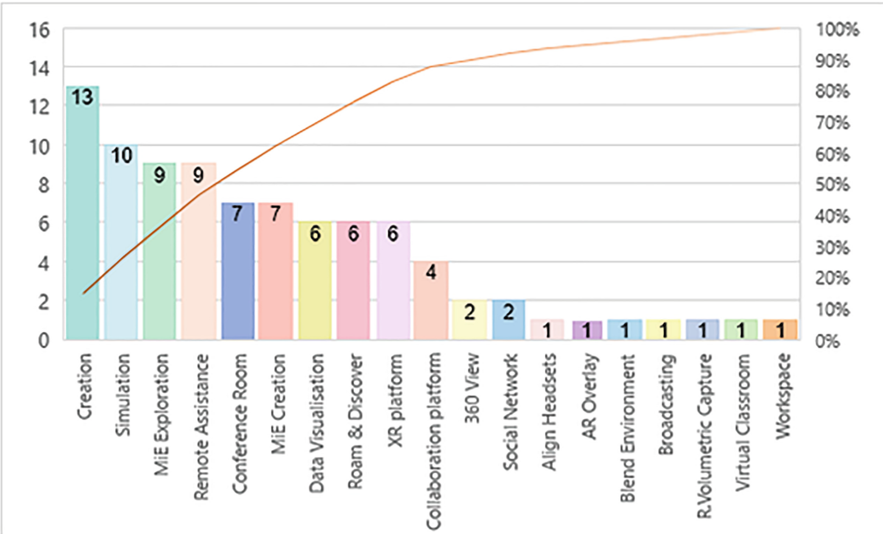

Fig. 3. The distribution of the categories of XR platforms

A Map of XR Experiences

When looking at the analysis in Fig. 4**,** what immediately stands out is the *escapist* quadrant is quite occupied. In this quadrant, the XR platform's experiences can immerse their receivers completely in virtual environments, where the receivers actively interact within these environments and memorize their visiting as 'places' instead of digital images.

In *simulating* scenarios that are complicated to build in the real-world, user tests might be done faster, easier, cheaper, and even remotely, especially for large-scale products, like aircraft interiors [15], ergonomic research [16], or urban planning [17]. Likewise, designing in XR can have benefits. Designer teams can work together globally and can test products with customers before major investments. *MiEE* is an interesting category for retail and design because the product can be seen in an intended environment, and it's even possible to turn, move or scale objects. Yet these are precisely where the interesting possibilities for the future lie. In addition, *Remote Assistance* can be advantageous by sharing the first-person view and involving stakeholders in contexts, where they can choose between immersive and non-immersive platforms. It would be beneficial for mutual understanding both assigning the designer's view to users and vice versa.

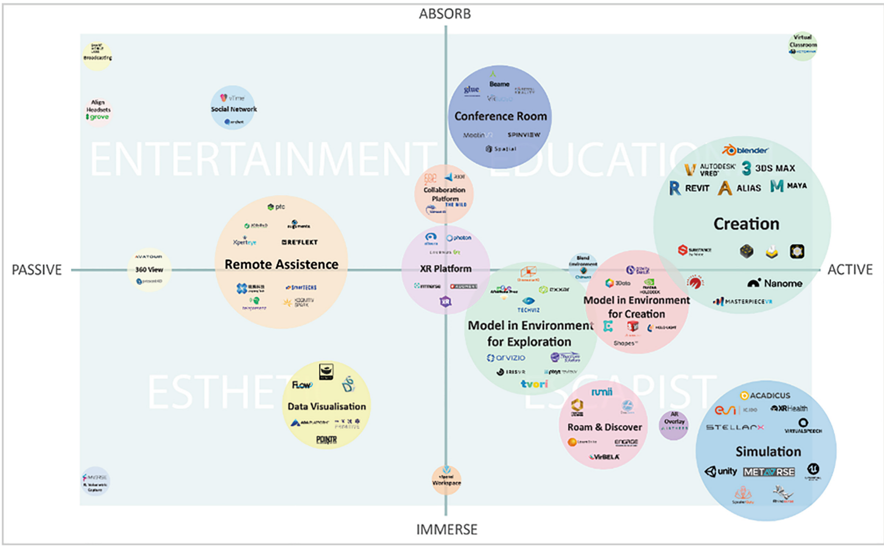

Fig. 4. The XR experience map - XR platforms following the Experience Matrix

3.2 Survey 2 – XR Platforms in HCD Processes

Method

As a thought experiment, the authors invented two personas of designers, a freelance designer and a corporate designer [18]. The freelance designer has a limited budget for software licenses and develops XR experiences by his/herself, while the corporate designer has more budget and can use commercial software and databases from the company. To clarify the differences between XR platform choices, a fictional design project is assigned to them, which requires creating an XR experience so that stakeholders can view a product in a particular context.

In Survey 2, the authors used a kitchen design as an example (see Fig. 5): CAD models simulated the requirements of a client, providing some parts in the kitchen, like a refrigerator and a stove. The cupboards need to be designed from scratch. It must be possible to interact with the drawers and kitchenware (like opening the fridge) in the VR demo. The authors discuss the general barriers of XR platforms and their implementation strategies according to the designer's personas.

The choice of XR platforms is then analyzed according to the two personas. XR platforms from the previous survey are analyzed to support HCD methods and tools in the fictional project. The XR platforms need to be assigned to the stages in the *Double-Diamond Model*: *Discover*, *Define*, *Develop* and *Deliver,* according to the methods and

Fig. 5. The fictional kitchen design project in virtual reality

tools listed in Table 1 [19]. If an XR platform is assigned to a certain stage, it means that it can support at least one or more design methods or tools at this stage. These XR platforms then are visualized on the DDM.

Table 1. The Double-Diamond Model and relevant design methods and tools [2]

Discover	Define	Develop	Deliver
- Observations - Questionnaires - Creating Focus Groups - SWOT analysis - WWWWWH - Design Drawing to Discover - Interviews	- Persona - Problem Definition - Function Analysis - Product Life Cycle - List of Requirements - Mind Mapping - Product Journey Mapping - Future Visioning - Collage - Storyboarding - Scenario creation - Design Drawing to Define	- Brainstorming - Brain-drawing - Morphological Chart - How-Tos - Design Drawing to Develop - Harris Profile - Usage analytics - ViP - Cost-price estimation	- Storytelling - Comfort Evaluation - 3D physical models - Technical Documentation - Design Drawing to Deliver - 3D Digital models

As need fulfilment is key to generating positive experiences, the authors also analyzed the selected XR platforms to understand how they can support to understand users' needs and requirements [20]. A hierarchical model of goals from the *Action Theory* is used in this survey (see [21]). According to this theory, *be-goals* represent the universal needs and values of human beings, and they motivate actions and provide meaning to them; *do-goals* refer to the concrete outcomes that a user wants to attain in an action; *motor-goals* drive people to press a button or click an icon.

Results

The Barriers of XR Platforms and Their Implementation Strategies

A common problem faced by designers is the steep learning curve. In addition, the learning and developing hours can pile up when complex materials (e.g., mirrors) or interactions (e.g., interactive objects) are involved. Different types of designers developed diverse strategies to cope with it (Table 2).

Table 2. Strategies used by designer's personas when developing XR experiences

	Obtaining assets	Interacting assets	Texturing	Effects
Freelance designer	Purchasing models from *Sketchfab* or *Asset store*	Developing objectives using *Blender* / *Rhino*	Mapping textures with *Materialize* or *Substance*	Applying basic/designated templates in *Unity* or *Unreal Engine*
Corporate designer	Company's database of models and imagery	Autodesk toolkit including *Maya* (animation), *AutoCAD* (manufacturer), *Revit* (architecture), and *VREDD* (automotive)	Autodesk material library shared by *Maya*, Revit, and *AutoCAD* or creating materials with *Mudbox*	Outsourcing to XR developers

For freelance designers, it is advantageous to use open-source software so that they save on license costs, and can invest in assets or training to save time. Freelance designers need to allocate learning hours alongside production hours to explore alternative pipelines, especially finding formats that can transfer assets between different platforms errorless. Changing purchased assets might cause errors as well. The corporate designer has more resources at his/her disposal, and there is already a stock database for images and models. They can concentrate on sophisticated design solutions. The corporate designer probably already has a high budget for an XR project. For complicated XR experiences, outsourcing is a time-efficient option. However, corporate designers have limited capacity to reuse the XR experiences afterwards. Moreover, many 3D engines, like *Unreal Engine* or *Unity* are often not compatible with enterprise engineering software.

The situation is changing due to the increasing need for XR experiences. Many simulations are recently been included in open-source programs like *Rhinoceros*. Both freelance and corporate designers now can create enough relevant XR experiences to help clients clarify or promote their products when they can master alternative pipelines. For example, many XR platforms (e.g., *Unity*, *Unreal*, *Substances*, and *Autodesk*) offer asset stores where designers can purchase models or templates, which would save a lot of time on modelling and animating. This offers an option for freelancers, who would demand a budget from clients to purchase assets to save production hours. With the accumulated experience in developing XR experiences, the assets, i.e., models, materials, code, and environment, could be reused in different projects.

Different Ways for Choosing XR Platforms in an HCD Process
There are different ways of choosing XR platforms in the sense of time and budget. For example, freelance designers prefer open-source software such as *Blender*, which is free to use but very limited on technical support; whereas corporate designers are bound to enterprise software like *Autodesk* which a one-year subscription per package costs between two and three thousand Euros. These licenses usually are decided by the company and include different types of services from technical support to customized development. On the contrary, freelance designers have more flexibility in allocating learning and production hours, whereas for corporate designers, putting in extra hours to learn new tools requires an agreement at the organizational level. Moreover, XR developing skills serve as a new competence for freelancers as well.

The design tasks are different as well. The freelancers can easily do simple assignments, which are similar to the tutorial provided by each XR platform. As the complexity increases, such as multiple environments, interactive functionalities, or specific objects to be modelled, freelancers bear instant rises both in learning efforts and workloads. Precisely with these complex assignments, corporate designers benefit from licensed systems, like the Autodesk toolkit. It consists of a set of software that works in a smooth pipeline. For instance, exporting models to another program is effortless and simulations can be configured with 'one-click' functions. Hence, corporate designers can focus on more complex and detailed design tasks. Designers have different platforms at their disposal that can facilitate different design activities. The survey listed selected XR platforms following the *Double-Diamond Model* (Fig. 6).

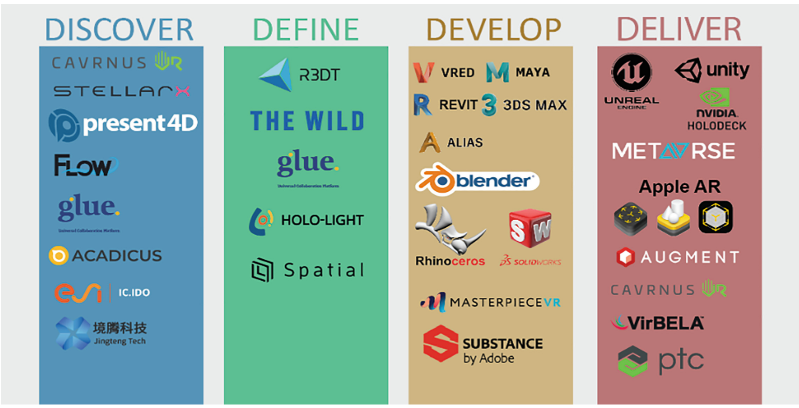

Fig. 6. The typical XR platforms in line with the DDM

The Discover Stage: IC.IDO, for example, supports replacing physical prototypes with interactive and digital mock-ups with real-time physics simulations in a team of six members. It enables remote observation with teams of up to twenty collaborators as well as a maximum of forty spectators. The platforms from the *Conference Room* category, like *glue,* focusing on casual co-working and review, which mostly share 2D video, presentation and desktop would be suitable for probe *be-goals* of users. The *Simulation* category with 360 videos and images, like the *IC.IDO* would help designers gain empathy under particular contexts. Other categories that help to understand be-goals are the *Data Visualization* and *XR platform.*

The Define Stage: Spatial.io is an online gallery supporting self-defined rooms for shared reviews with forty collaborators. *R3DT* and *the Wild* emphasize remote collaboration that allows a twenty-person team to use CAD data for visual prototypes. *Holo-light* can create co-work AR space to inspect, manipulate and share engineering designs. When a platform from the *Conference Room* or *Collaboration Platform* categories that share 3D assets or CAD images, like *the Wild*, it's suitable for defining a particular design problem and its relevant do-goals. The *MiE Creation* category (e.g., Holo-light) enabling visualizing, manipulating and sharing CAD data immersive could support the survey on do-goals alike.

The Develop Stage: The software, for modelling and prototyping, is *VRED*, *MAYA*, *ALIAS*, and *3DS Max*, or open-source software like *Blender* and *Rhinoceros*. *Substance* from Adobe focuses on 3D materials for photorealistic rendering. *SolidWorks* from Dassault Systems also puts efforts into direct modelling in VR. The XR interfaces of SolidWorks and Rhinoceros can help designers to check the ergonomic issues (like sizes, visibility, and reachability) with intuitions. When reviewing the early prototypes with stakeholders, designers can easily check the fulfilments of the *do-goals* and *motor-goals* with a specific design proposition.

The Deliver Stage: XR experiences need to be released across different hardware, where the most common ones are headsets, iOS/Android smartphones, or web browsers. Additionally, advanced interactions and animations, like physics effects, are mainly made via 3D engines, like *Unreal Engine*, *Unity,* or *MetaVRse*. AR applications are popular ways to reach clients on smartphones or tablets, which are developed by *Apple AR* or *Augment*. The *HOLODECK* from NVIDIA targets a VR innovation platform to involve design teams and stakeholders. *Cavrnus* and PTC *Vuforia Chalk* can support both the *Discover* and *Deliver* stage. *VirBELA* is a web-browser-based virtual campus that provides online presentations, meetings, conferences, and customized events. XR platforms at this stage need to deliver the essence of a specific experience as a whole to stakeholders, particularly end users, and thus shall review all levels of goals together. The platforms belonging to the *Simulation*, *Creation*, and *XR Platform* categories might fulfil this requirement.

4 Discussion

4.1 Survey 1

The categories of XR platforms still focus on *Creation* and *Simulation*, among which *Unity* or *Unreal Engine* are the most-used tools to create advanced interactions and narratives in XR experiences. As already explained, in the future the *Simulation* category will be helpful to train employees in different cases or test the experiences of product-service systems. It's worth noticing that the categories supporting remote collaboration in different levels of immersion, such as *MiE Exploration*, *Remote Assistance*, and *Conference Room*, become popular as well. A possible speculation is their attributes might link the design activities with marketing activities, which seems to accelerate iteration loops in design processes.

In the XR experience map, the *immerse-active* quadrant is more occupied compared to the other three quadrants. A possible explanation is that being immersed in a virtual environment is seen as active as you need to navigate and grab objects. Immersing and spatializing experience not only helps to transfer design problems to solutions but also enriches the emotional component of designers' work [11]. Compared to a real-life PowerPoint presentation, presenting in a virtual environment can be immersive to the receivers, but the presentation tools would be relatively absorptive compared to other XR platforms. Therefore, when it comes to immersion, the axis is relative to XR experiences as XR is generally seen as an immersive tool [22]. The absorptive experience is less represented by current platforms. Pine, B. J., & Gilmore, J. H. states: "*If the experience "goes into" guests, as when watching TV, then they are absorbing the experience (…)*" [14]. The absorption thus might as well invite high mental engagement which is very important in design communication. For instance, designers walk through an immersive environment while sharing their viewpoints with stakeholders on desktops or tablets to enhance mutual understanding.

4.2 Survey 2

To create a positive, valuable, and meaningful experience in a product-service system, it is important to satisfy universal needs and values, like emotional connection, affection and other experiential aspects [23]. Experience approaches thus show the possibility to solicit multisensory sensations, such as vision, audition, and touch. It might not only facilitate the assessment of pragmatic qualities, but also appraise the hedonic qualities, such as familiarity, pleasure, and communication [24]. Moreover, sometimes there are different conditions where the real-time involvement of stakeholders can be challenging [9], like limited time, accessibility of contexts, and ethical considerations [25]. There is thus a shift from the technology-focused perspective to experiential approaches, where the first-person perspective enables design professionals to collect subjective experiences as rich as possible for analysis [11, 26].

When it comes to implementing XR platforms in design, the first look is the costs. There's a trade-off between license expenses and asset purchases. For freelance designers, the expenses on licenses shall be as low as possible, while the budget for buying assets can be higher. To corporate designers, the situation is reversed because they already have enterprise dictionaries at their disposal. Design assignments leverage the license-asset balance as well. Thinking of a kitchen design as shown in Fig. 5, freelancers can produce XR experiences with standardized kitchen models and 'one-click' XR functions at a very low cost. As customized requirements increase, corporate designers have more resources that allow them to collaborate with colleagues and create detailed solutions that are impossible for freelancers.

In terms of time, designers so far probably need longer for learning than for producing at the beginning. When simulating sophisticated interactions, the learning curve can go even steeper. Another barrier, in terms of time, is the threshold to embed XR into design processes, in that design teams need a smooth workflow that links XR platforms with current pipelines. The errors occurring now frequently on incompatible file formats consume a lot of development hours. Regarding using XR in user testing, there's a learning gap as well because designers need to train users to understand the navigation and controls at first. Therefore, using XR platforms without thinking about them is the key to increasing the application rate.

5 Conclusion

Extended Reality, as a growing trend in digital transformation, is still evolving but has shown great potential for global economic and technological growth soon [27, 30]. Considering the rapid growth in computational power, especially in AI design [31] and graphic computing [28], it would be possible for everyone to create their own XR experiences soon. The next focus would be the improvements on interfaces of XR software and hardware, so it becomes intuitive both for ideating and developing tasks. More and more researchers put their efforts into the human factors of XR platforms, and many developments are expected in this area. It is therefore an interesting field to monitor in the coming years.

Several limitations in this work might pinpoint room for future studies: (1) Many simulation games or similar applications that serve as a good representative real-world experience are not included in this study. The analysis of how games can simulate corresponding experiences might be beneficial to designing relevant product-service experiences as well. (2) Experience by nature is memorable, as well as unique and irreducible [14, 29]. Hence, XR simulations should not merely focus on photorealistic appearances but also on generating relevant narratives. (3) The participation and connection axes of the experience model could be correlated. More specific analyses on immersive factors are needed. (4) Design agencies or small teams, who are both limited on time and budgets, are missing in this analysis. Further studies will involve different roles of designers to understand their needs and expectations of XR platforms.

The ability to observe from the first-person perspective, such as looking inwards, looking outwards, backwards into the past, and forward into the future, is as significant as the third-person view, like observing the user's eye movements, in understanding human needs and emotions [26]. XR platforms show the potential to integrate both of them in the future. Additionally, remote design is never as good as when people are together, but XR might offer a different solution. The authors can be cautiously optimistic that when the interfaces of XR hardware and software become intuitive, designers will be empowered to create what's impossible to experience now.

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