Opportunities of Social VR in Digital Museum Twins

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ABSTRACT: In the past, virtual replicas or digital twins of a real museum, provided single users with graphical representations of the virtual environment. Single-users of VR applications experience an isolated and lonely environment and are known to miss rich, social, and shared experience. Collaborative Virtual Environments (CVE) allow for experiencing virtual environments together with other, which we learnt from the physical environment, is natural to us as we consider ourselves as social beings. While multi-user VRs provide rich user experience (UX), it is still not understood how to design a multi-user VR. This paper highlights opportunities of multi-user VR and proposes interaction design ideas that promise to guarantee rich UX.

1. INTRODUCTION

Designing virtual environments with rich user experience (UX) is challenging. It is commonly known that existing virtual reality (VR) exhibitions are not visited as often as theoretically possible via the web. In previous work, we compared a physical museum, the Museum Otto Weidt's Workshop for the Blind with its digital twin to understand what we win and what we lose during the transition from real museums into a virtual replica [39], see Figure 1.

We found that pure VR indeed has benefits in comparison to real museums, as space, time, location, and money are no barriers of museum visits. Moreover, authenticity and sensation of space get lost in VR. Media augmentation, interaction, and gamification are promising concepts for augmenting virtual exhibitions, while the augmentation content has to fit the exhibition concept, and some content may be not appropriate to be virtualized, e.g., original artefacts, and some content may not be appropriate to be augmented, e.g., information of sensitivity.

Imagining a perfect digital twin still cannot compete with the experience a museum visit with a friend on a Sunday afternoon where we not only enjoy cultural experience, but also chat with a friend and share the thoughts and experience during the exhibition visit. Therefore, we advocate the social aspect of museum visits as key aspect that forms experience. We argue that single-user VR can only be the first step towards rich virtual experience, and that multi-user VR enables social experience, fun and joy, collaboration, communication, learning and opinion exchange and consequently the possibility to create virtual environments that embed the aspects that make our physical world enjoyable and our life interesting.

In traditional single-user virtual reality (VR), for example, virtual replicas or digital twins of a real museum, users are provided with graphical represen
tations of the virtual environment with which they interact alone. However, it has been shown that single-user VR applications are an isolated and lonely experience that lack in rich, social, and shared experience. With the recent possibilities of modern networks and the availability of consumer VR hardware, suitable solutions for Immersive Collaborative Virtual Environments (CVE) have only been possible for a short period. CVEs are the result of merging the research communities Virtual Reality (VR) and Computer Supported Collaborative Work (CSCW) [1]. Such multi-user VR systems are increasingly utilized to support collaboration between geographically separated and co-located collaborators. In advantage to single-user VR, multi-user VR closes the gap of social isolation and loneliness by integrating the social component. While multi-user VRs provide rich user experience (UX), it is still not understood how to design a multi-user VR. This paper highlights

Figure 1: *Digital Twin of the Museum Otto Weidt's Workshop for the Blind [39].*

opportunities of multi-user VR and proposes ideas that promise to guarantee rich UX, for example, in virtual museums that we visit with friends.

While real museums and exhibitions must deny the entry of additional visitors for security reasons and to prevent overcrowding, we assume that in future digital twins of museums and exhibitions might be visited by an enormous large amount of people. Such multi-user VR potentially creates crowded virtual situations in which numerous participants visits virtual places simultaneously, either with known people or simultaneously with strangers. These users may dynamically form new socially active groups [2] and interact with the environment and with each other, but they also might distract each other, occlude views on virtual scenes, or occupy interactive objects. When exhibitions are frequented by many visitors, it can happen that we feel disturbed. The reasons for this are that many visitors in an exhibition take the opportunity of free movement, obstructing the view of objects and exhibits, disturbing the communication and the social experience with our companion. Who has never wondered how nice it would be to explore an exhibition alone in company. Who has never wondered why this person blocks my view of an exhibit and who never wished to just walk through that person. The design opportunity that we highlight here can be described as *overcrowded VR.*

In multi-user VR, users can interact socially with each other, explore the environment together, and interact together with virtual objects. In collaborative scenarios, it may be helpful to know what our companion is seeing. It would be very useful to share the personal direction of gaze to give the companion the opportunity to view the objects and exhibits of the personal view or steering the companion view to this. This could help to draw attention on details that are hard to show by non-verbal communication and to describe by verbal communication. While multi-user VR may allow users to share their own viewpoint and to indicate to others where they look at [2], new design opportunities, such as view sharing techniques and VR privacy occur. The design opportunity that we describe here focuses on VR *view sharing*.

Multi-user VR may also enable participants to discuss and manipulate shared 3D models and visualizations in such a way that they beneficially collaborate with each other, but users may also interfere the action of others or create chaos through uncoordinated interactions.

The third opportunity is closely related to view sharing as it occurs in collaborative scenarios. When interacting with digital objects, for example, opening a book or starting a movie, we face the question whether or not the object interaction should be visible for each user, only for the user who started the interaction so that other users can act in their parallel VR or if such agency of control should be dynamically adapted to the situation. We entitle the design opportunity as *agency of control management*.

2. RELATED WORK

Research in CVEs shows that there is a multitude of problems to be solved. The research in multi-user VR must verify whether these approaches and results can be applied in the same way or whether they need to be rethought. A requirement for interaction in CVEs but also in multi-user VR is that multiple users can act simultaneously on the same object.

2.1 COLLABORATIVE MANIPULATION

A large body of research was made for CVEs in collaborative interactions and manipulation with and on virtual objects. To support object co-manipulation, two general approaches exist. Pinho et al. investigated the simultaneous interaction of two users with a single object [3]. They enable co-manipulation by splitting the degrees of freedom for the virtual object. Each user manipulates particular degrees of freedom for the virtual object, such as on control the translation of the virtual object the other control the scaling of the virtual object.

There are two approaches of techniques that allow remote users to manipulate a virtual object together. To achieve co-manipulation, CVEs, as well as multi-user VR, needs to manage concurrent access to an object by combining inputs from multiple users (i.e. [4, 5]). Moulec et al. investigates the transfer (the takeover) of the interaction control of an object between two or more users [6]. Hosseine et al. investigates visibility-based interest management mechanism in CVEs based on each user's visibility of others [7]. Lopez et al. explored how virtual agents and real users work together as equal team members to a common goal [8].

2.2 VIEWPOINT AND VIEW CHANGE

Multi-user virtual reality systems enable natural collaboration in shared virtual worlds. Users can talk, move, and point to virtual objects as if they were real. As in reality, observing objects or referencing them by pointing often leads to a situation where objects are obscured by the other user's viewpoints. while the only chance in reality is to change the viewpoint position to solve this problem, VR allows other ways to deal with this problem. Argelaguet et al. investigated multi-user pointing with show-through techniques [9]. They found, that show-through techniques can improve collaborative interaction tasks when inter-user occlusion problems in multi-user virtual reality systems occurs. Piumsomboon et al. share a local Augmented Reality (AR) user’s reconstructed space with a remote VR user who has an ability to scale themselves up into a giant or down into a miniature for different perspectives and interaction at that scale within the shared space [10, 11]. Zhang et al. [31] report the results of an experiment, which show the impact of multiscale capabilities on social interactions. Chastine et al. sharing the same viewpoint between users with the help of semi-transparent avatars [12]. Fukatsu et al. investigated a manipulation technique to intuitively control the "bird’s eye" overview display of an entire large-scale virtual environment [13]. It enables efficient navigation even in enormous and complicated environments using both global and local views. Yang et al. explored ways of dynamically integrating others’ perspectives and incorporating different views into a single interface for 3D CVE users.

2.3 VIRTUAL HUMANS AND AVATARS

Human factors are also crucial to the design and effective use of multi-user VR as a new type of social community. An extended body on research of human factors was made in the research of CVEs. The research of Becker and Mark investigated whether the social conventions in the real world are still applicable in the common virtual world [14].

The results of this research indicate that virtual environments have characteristics as well as exist in social systems and found that contacting greeting is an important convention that serves to initiate contact and influence the subsequent interaction, distances between avatars have established group affiliation and privacy, conventions of courtesy are maintained, but gestures and facial expressions were rarely used.

Virtual humans represented as avatars are computer-generated characters that visually correspond to humans. Steed and Schroeder identified avatar realism as one of the main factors that affect interpersonal interactions and co-presence in VR [15]. A large body of research has examined its appearance and behavioural realism and how it affects people's response.

Visual realism can be influenced by a number of factors. Different approaches have been developed to create and animate virtual humans and their movements, gestures and facial expressions [16–23]. McDonnell et al. investigated the style of representation of virtual humans. They found, that participants rated cartoon faces with lower realism as more attractive and friendly than more realistic faces [24]. Cuddihy and Walters explored user embodiment in typical desktop VE and how the virtual representations (simple object, robot, humanoid avatar, etc.) influence their communication [25]. An increased sense of presence makes it possible to draw the user into the VE, to lift their unbelief and to attract their attention. They conclude, that techniques for increasing a user's sense of presence are important. Roth et al. investigated the effect of abstract avatars, without display gaze, facial expressions or social cues [26]. Their results show significant differences in terms of presence and physical performance.

George et al. investigated how the avatar design impact trust in immersive VR (IVR) [27]. They found, that human-like avatars was perceived to create a more intimate level of togetherness and felt more comfortable when in the presence of the human-like avatar. Schwind et al. investigated how the appearance of the virtual hands influences the user experience [28]. The results show that deviations in the virtual representation of the hand from reality can affect the tactile experience. Also, subjective feedback from study participants showed that inconsistencies between the visual and haptic experience caused distractions. Makled et al. examined the effects of full body and head movement in terms of viewers' perception [29]. Their results suggest, that various body part animations affect the realism and the comfort of perception of the viewer. They also found that body animations are more important than head movement. Kauppinen et al. investigates the relevance of gender in three different VEs to producing identity [30]. They found, that gender plays a significant role in VEs. Their research also confirmed the convention detail of the results Becker and Mark [14].

Behavioural realism can also be influenced by a number of factors. Bailenson et al. investigated interpersonal distances and personal space [31]. They found, that participants maintained typical interpersonal distances. They also found, that user of IVR disliked the violation of their personal space.

In order to improving social presence in virtual reality, Hai et al. investigated behavioural realism and realistic interactions with a focus on multi-user VR where agents and avatars interact, share and collaborate with each other using objects [32]. They found, that realistic interactions in object driven interactive multi-user VR plays an important role. Garau et al. [33] examine the effects of visual and behavioural realism in avatars on the perceived quality of communication in an immersive virtual environment.

2.4 SOCIAL VR

A social VR system is a multi-user VR system that allows multiple users to connect to CVE and communicate with one another, usually through visual and audible cues [34]. Each user is represented in the VE as a computer-generated avatar [35]. In recently proposed systems they could also be represented with a virtual representation based on live captures [36–38]. VR social networks have emerged, and companies such as AltspaceVR, Facebook or ... provide virtual spaces in which users, represented as avatars, come together. In these spaces, they get the opportunity to interact and communicate together, even though their physical presence is often geographically far away.

Gunkel et al. [36–38] addresses the limited interaction of previous Avatar-based

approaches, as they offer no real interaction and are too limited for applications such as video conferencing, presentations, 360-degree videos, and much more. They developed a web-based VR framework that extends current video conferencing capabilities with new VR functionalities. They found in a survey, that 47,25% of their study participants are interested in Social VR experiences. They also mentioned that "experience interaction" and "enjoyment of the overall experience" are considered important by more than half of their participants [38].

CVEs also have the potential to support crowded situations in which a large number of participants visiting virtual places simultaneously with known people, but also dynamically forming new socially active groups [2] and interact with the environment and other users. Finally, CVEs may enable participants to discuss and manipulate shared 3D models and visualizations in such a way that each can adopt their own viewpoint and can naturally indicate to others where they look and point [2].

As already introduced, it is not clear whether the solutions and approaches from the adjacent research areas can also be applied to multi-user VRs and yield to the opportunities for multi-user VR.

3. DESIGN IDEAS FOR DIGITAL MUSEUM TWINS

While interaction design guidelines for desktop computing and interaction with 2D content has been investigated for decades, interacting with in 3D environments, especially with many users, is still not completely understood. One major research goal is to identify the specific interaction opportunity for the digital twin in overcrowded situations while ensuring social interaction with the companion. The virtual environment is not necessary bound by the laws of physics and the nature of our reality. VR offers the opportunity to deviate from the limitations of physical reality to experience other forms of physics. We believe, that the design space of interaction techniques in VR would be much richer if we are not limited by real-world physical laws.

In this paper, we describe design ideas that help overcoming the opportunities described above. We propose several design strategies to overcome overcrowded VR, such as eliminating the collision of virtual visitors' avatars or introducing a social slider that allows the user to determine the number of co-users in the same VR. We further propose to downsize others' avatars, which automatically reduces the visibility of these users, which alternatively can be solved through regulating the transparency of their avatars. Furthermore, we introduce a multiverse, which describes the option to have parallel virtual realities in which users can act at the same time without disturbing each other to address the opportunity of agency of control management. Finally, the opportunity of VR view transparency (GhostVR) or of sharing the view of other users.

3.1 CHALLENGE OF OVER-CROWDED VR

Overcrowding or crowding is dependent on the current environment and local cultural norms and refers to the condition in which more people are in a particular space than is tolerable from the point of view of safety and health. Problems, such as safety and health may not play a role in overcrowding situations in virtual exhibitions and museums. However, when we treat the virtual replication as it does reality, we face the same issues as blocked paths, limited visibility, too much visitor distraction, lack of orientation, confusion, and interactive media occupied by other visitors. These problems are conditioned by the physicality of the real world. By omitting certain physical laws and principles, ways can be found to circumvent these problems and create a new rich user experience. In the following, we will describe a concept in which the user of a virtual museum might gain control over overcrowding and make suggestions how the resulting problems could be solved.

3.2 OMITING COLLISION

We propose the control of collision absence, displacement and materiality of bodies in VR. Due to the physical laws of the real world, we cannot take the same position of another person. In VR, we have the opportunity to experience other forms of physics. The chosen approach is the easiest way to deal with overcrowded situations, not directly addressing the problem of overfilling but much more addressing the problems arising from overcrowding, such as obstructed paths and obstructed visibility.

3.3 SHRINKING CO-USERS

The concept of omitting collision between avatars in virtual exhibitions might be useful to walk through avatars that occlude our view on exhibits or to walk through avatars that stand in our way, but imagining overcrowded virtual exhibitions with a million users would probably still not lead to rich UX. We moreover assume that we want to have a high perception of co-presence with co-users we know, but there might be many co-users whose presence would distract our attention. Hence, we propose a social slider, which allows to set the level of perceived co-presence for avatars on an individual level. While we surely want to feel rich co-presence with our friends when visiting an exhibition together, other visitor groups are probably not important to us. Whose avatars could be faded out with a concept that we call *social slider*. Such slider might shrink particular avatars and/or decrease the transparency of their visualization.

3.4 CREATING MULTIVERSES

When we are with friends in a museum, sometimes one person wants to get information about one topic while the other person is more curious about another theme. VR allows to create multiple virtual realities, and we propose to consider multiple versions of an exhibition, especially when users watch multimedia content or listen to audio information. Such representation of virtual environments particularly considers Wickens' multiple resource theory, which indicates that we cannot read text when a voice is telling different content [41]. Therefore, especially for content that has voices and speech, multiverse VR is highly recommended to manage the cognitive load and attention of users.

3.5 ENHANCING CO-PRESENCE THROUGH GHOSTVR

When we are in the same virtual environment as a co-user, we do not necessarily see where the other user is or looking at. Sharing information what content our companion is currently seeing could add to the social experience in VR. We earlier proposed to visualize where a co-user is located through an aura around their position or where they are looking at through a field-or-view frustum indicating the field of view of the other users [40]. Furthermore, VR offer view sharing through switching between our own field of view and one of any or certain co-users.

4. CONCLUSION

In this paper, we provided an overview of work on multi-user VR and moreover highlighted how such virtual environment challenges social experience or how the occurrence of multiple users challenges the experience of content perception, for example, in a virtual exhibition.

We proposed several design strategies to overcome overcrowded VR, such as eliminating the collision of avatars or introducing a social slider that allows the user to shrink co-users in the same VR or to make them transparent or even invisible. We also proposed a multiverse, which describes the option to have parallel virtual realities in which users can act at the same time without disturbing each other. Finally, the opportunity of seeing where other users look at or what they see is proposed to guarantee rich social VR.

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