Exploration of Visual Transitions Between Virtual and Augmented Reality

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ABSTRACT

Mixed reality devices that support virtual reality as well as augmented reality have become popular in the recent years. In the following position paper, we address important challenges that arise with these new possibilities. *How to realise a seamless transition along the virtuality continuum on the visual level?* Especially in immersive analytics, techniques for seamless transitions between VR and AR would greatly increase the visualisation and collaboration possibilities. We will provide an overview of existing literature and an initial pre-selection based on criteria for immersive analytics to open the topic for a joint discussion.

KEYWORDS

immersive analytics, visual transitions, virtual reality, augmented reality

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INTRODUCTION

Mixed reality (MR) consisting of virtual reality (VR) and augmented reality (AR), has been a very popular research topic since the first head-mounted displays (HMDs) were developed and is still a hot topic. Due to the continuous hardware improvements, MR is now becoming more and more established in all areas of industry as well as in the consumer market. In immersive analytics (IA), both VR and AR have been used for data visualisation in a wide variety of applications.

In AR, HMDs can be distinguished between video see-through and optical see-through devices to superimpose graphics [8]. There are many trade offs between optical and video see-through HMDs, for example video-based systems usually have a larger field of view than optical systems and can handle the occlusion more easily because they can block it on a per pixel basis. However, the perceived resolution of the real scene is limited by the resolution of the video cameras or the viewing optics. A viewpoint mismatch can also cause a problem, as the viewpoints of the cameras must be the same as the viewpoints of the eyes, otherwise the user will experience a spatial shift. These trade offs should be taken into account, as the quality of the transitions can be influenced by the selected hardware. For example, it could be difficult to find the portal if the field of view is too small.

Current HMDs like the Oculus Quest or the HTC Vive Pro are equipped with additional cameras used for tracking purposes or for providing additional user safety. But also devices like the Sulon Cortex or the Varjo XR1 focus on providing video see-though capabilities.

The next logical step for MR hardware is to combine a VR mode and an AR mode in one device. The advantages of both modes can be combined, for example, the bigger field of view for AR applications, due to the optics and the display of the video see-through headset. The user of such a device could now choose and switch between a VR experience and an AR experience. This is not a fully novel idea but due to the improved hardware in VR and AR the topic is getting more attention in the industrial and consumer market. Especially in IA, a combined VR and AR mode would offer many possibilities and eliminate some main disadvantages of the respective technology.

COMPARISON OF AR AND VR IN THE CONTEXT OF IMMERSIVE ANALYTICS

Both technologies provide a set of advantages and disadvantages when they are used in the field of immersive analytics. Designers and developers often have to choose an appropriate technology.

Advantages of VR.

- **Wide Field of View (FOV)** - The wide FOV provides a better overview on the data. Current optical see-trough devices or mobile devices in AR often provide a very small FOV.
- **Isolation from real world** - The user wearing an HMD is isolated from the real environment and is not distracted during data analysis. Place illusion, giving the user the impression of being at a different location [11] is achieved.

- **Arbitrary display space** - With a VR based environment the display space and work space in the virtual world is unlimited.

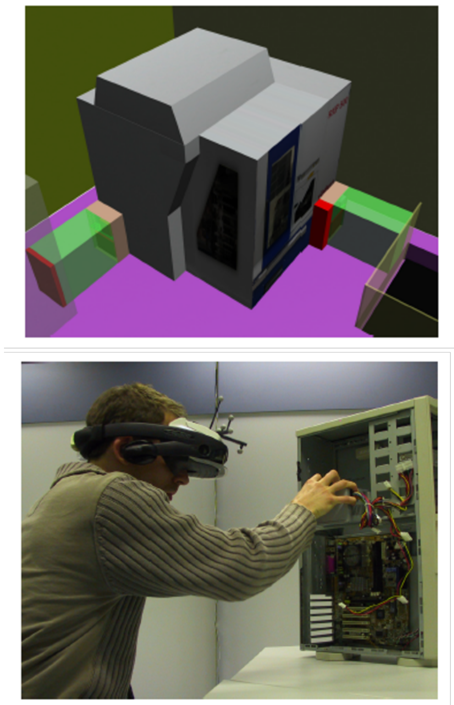

Figure 1: Transition in production environment, with VR Preview and AR Manual [3]

Advantages of AR.

- **Collaboration** - In AR environments users can perceive each other and communicate without being mediated through virtual representations.
- **Tangibles for real world reference** - AR allows the inclusion of real world objects, which can be enhanced with visualisation data.
- **Mobility** - AR applications can be used anywhere. Dedicated interaction spaces are not required, since the users can still perceive the real environment.

MR technologies share the feature of head tracking which allows the user an exploratory analysis of data sets and take uncommon perspectives on the data. AR based HMDs also share with VR the possibility to perceive the environment in a stereoscopic mode improving the perception of spatial structures.

Applications like VITA [1] make use of an AR and a VR mode for analysing data of an archaeological dig site. Isolation is required to fully dive into the dig site, but also collaboration of the users should be supported.

One of the first publications in this field originates from Kijima and Ojika [4]. They created a transition between the real workplace with a traditional monitor and the work in the augmented environment. Thus the advantages of both techniques remained available. For the transition between the environments, they used the position and orientation of the head to switch between these environments. If the user looks away from the monitor, the virtual environment starts via a optical see-through HMD. It is also possible to stand up and explore the virtual objects, providing the user with a natural interface to switch between them. They also implemented an object transition, where the user can grab a object from the monitor and place it in the surrounding virtual environment.

Eissele et al. [3] present a system for a transition between different reality-states in a production environment (Figure 1). In order to change from VR to AR, a certain mounting position of the model must be selected, then the entire environment is changed at once. The result of the usability test showed that participants with MR support were faster than participants with traditional support. However, the transitional technique is not explained in detail.

All these approaches show the need for AR and VR visualisation, but provide a hard cut between the different modes. As a result of a combined MR device, the visual transition between VR and AR is becoming increasingly important and it is therefore time to pick up on this topic again.

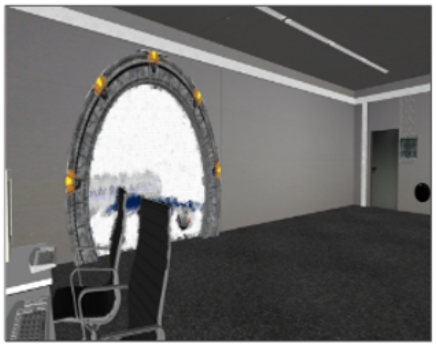

Figure 2: Virtual replication of the real laboratory with a portal transition to the airplane [14]

[1]https://support.oculus.com/guardian/

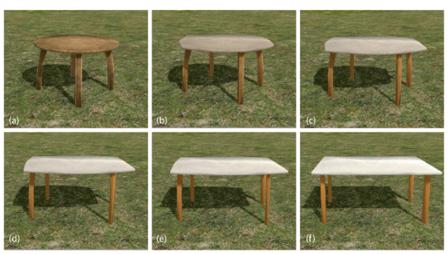

Figure 3: Morphing the table by changing the shape and texture [10]

SEAMLESS VISUAL TRANSITIONS

There are multiple ways to create such a seamless visual transition from the fully virtual environment to the extended real world. Many reasons exist why a seamless transition is desirable and should be properly designed. On the one hand, the workflow should not be disturbed due to orientation problems and on the other hand plausibility should be maintained [11]. In addition, the user should be able to easily collaborate with others without being confused by the transition. In order to achieve these objectives, the possible transition techniques need to be carefully studied and evaluated in terms of their quality. The term *seamless* was described by Satyanarayanan et al. as a potentially disruptive state change that, however, hardly distracts the user [9]. As an example they mention the transfer of the mobile phone between two access points where the user does not notice the transition. In the context of VR and AR, this could mean transferring the user without being disturbed in his work.

In order to find good transition techniques, it is necessary to compare existing visual transition techniques from literature and in well-designed applications, tech demos or games, such as Oculus' see-through Guardian[1].

SEAMLESS VISUAL TRANSITIONS IN MR

The section is divided into two parts, with the first part focusing on the transitions between different VR environments. These presented approaches can be applied to a transition between AR and VR. Since combined MR devices have not been used often in recent years, the number of research for transitioning between between AR and VR is limited.

Seamless Transitions between Different VR Scenes

Steinicke et al. [14] dealt with the question of whether a transitional environment increases the sense of presence in VR or not. A prototype with two scenarios was created for the user study. In the first one the virtual flight experiment directly starts in the airplane. In the other scenario a virtual replication of the real laboratory environment was created. Inside this environment was the portal to the virtual plane (Figure 2). The participants were now able to physically walk though the portal to start the flight experiment. During the transition into the other environment a 3 second long animation sequence with convincing sounds was played. In their study they used the Slater-Usoh-Steed (SUS) presence questionnaire [15], which led to a significantly higher assessment of the user's sense of presence. In a further publication, Steinicke et al. [13] investigated the improvement of distance perception with a transitional environment.

Sisto et al. [10] used various transition techniques in their work and examined whether the users noticed that the environment was changing or not. The transition from a quiet environment in the

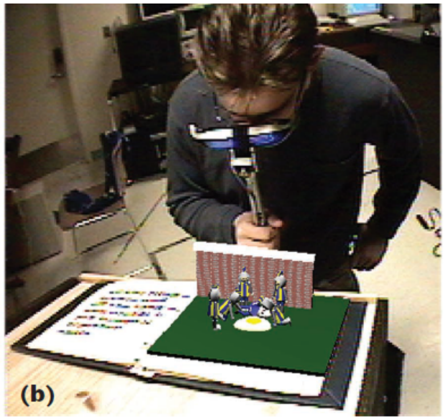

Figure 4: Fly with AR into the scene and perceive it as a VR application [2]

Figure 5: Magic Beans Demo using a portal to create the transition [2]

[2] https://www.youtube.com/watch?v=pp90zGjydwI

[3] https://superhotgame.com/vr/

middle of nature to the actual working environment took place gradually as the tasks progressed. The following transition techniques were used:

- Fade In/Out
- Scale Change
- Position Change
- Morphing (Figure 3)
- Offscreen Appearance/Disappearance
- Fragmentation
- Sound Transitions

The user study demonstrated that most of the transitions were not noticed and the changes did not interfere with the user tasks.

Three other transition techniques can be found in the work of Men et al. [5]. These were *SimpleCut*, *FastMovement* and *Vortex* transition. Similar to Steinicke et al. [14] they investigated the effects of transitions on user experience and presence in VR. The study showed that *SimpleCut* maximises presence consistency while the more visible *Vortex* transition effectively breaks the presence.

Moghadam et al. [7] examined the impact of transitions on spatial awareness and sickness using three transition techniques. The paper includes references to the subject areas of travel, teleportation and view transitions in VR which could be important for further techniques. In another paper from Moghadam and Ragan [6] they were looking at transition techniques in immersive 360 movies. This could provide insights into techniques that are used in another area of VR experience.

Valkov and Flagge [16] follow the basic idea of a smooth immersion in the virtual environment in which the transition process consists of several components. As a transition technique, they used a gradually morphing environment form the replica to the target environment.

Slater et al. [12] have performed an experiment in a virtual replication of the laboratory. As a transition object they used a door that brought the participants to a new virtual location. A similar technique is used in the VR Game *Superhot VR*[3], where the transition object is a virtual VR headset. Both transition objects are using a portal transition to change between scenes.

Seamless Transitions between Reality, AR and VR

Billinghurst et al. [2] developed the MagicBook to explore the transition between reality, AR and VR in a collaborative environment. The application augments a real book with additional content but it is also possible to read the book without any technology. As a transition technique to VR, the user can fly into the scenes and perceive it as a VR application (Figure 4). To change from reality to AR, the user just needs to point the handheld display to the book. The transition from AR to VR, can be

Figure 6: User created portal to change the environment [4]

[4]https://www.youtube.com/watch?v=ICEegHQcZlc

Technique	visible	distraction	plausibility	applicability
Fly from AR to VR [2]	High	High	Medium	Hard
Blink (all at once) [3], [18]	Medium	Medium	Low	Easy
Portal [14], SRWorks, Magic Beans	High	Low	High	Normal
Fade In/Out [11], [18], [6]	Low	Low	Low	Easy
Scale Change [11]	Medium	Low	Medium	Normal
Morphing [11], [18]	Low	Medium	Medium	Hard
Appearance/ Disappearance [11], [18]	Low	Low	High	Normal
Fragmentation [11]	Medium	Medium	Low	Hard
Simple Cut [6]	Low	Medium	Low	Easy
Fast Movement [6]	High	High	Medium	Hard
Vortex Transition [6]	High	High	High	Hard

Figure 7: Different transition techniques in comparison

triggered via a switch on the device. For better collaboration, AR and VR users can see each other through a user representation.

In the area of HMD hardware producers, multiple tech demos of companies producing video see-through HMDs exist, illustrating the use of transitions between real and virtual space. The Sulon Magic Beans Demo presents a portal integrated into the roof of a real room an supports the transition from real to virtual space through the narration of a fairy tale (Figure 5). Technically spatial knowledge of the real environment has to be availble. HTC demos with SRWorks (Figure 6) portals to create a possibility to change between VR and AR mode.

POSSIBLE SOLUTIONS

To describe seamless transitions between VR and AR in immersive analytics a classification between the most promising transition techniques based on related Work (Figure 7) has been developed. The classification was made according to the following criteria:

- Visibility, how strong is the transition visible?
- Distraction, how much do I get distracted by the transition?
- Plausibility, how realistic does the transition feel?
- Applicability, is the transition applicable to many different application scenarios?

The evaluation scale ranges from low to medium to high, except for applicability, where it ranges from, easy to normal, to hard. In the area of IA, the transition should be discreet and not conspicuous so as not to distract from the data. The transition should be comprehensible, as you are usually in a realistic scenario (simulated workplace) to analyse the data. Based on these criteria, two promising transitions would be *Fading* and *SimpleCut*, as these are visually unobtrusive and rather not distracting. For IA, however, a *Portal* could also be used as a transition. The portal transition is reasonably plausible, as it works similar to a real door that gives access to a new environment.

FUTURE WORK

One of the next steps should be the implementation of the most promising techniques in context of an immersive analytics prototype. The techniques should then be evaluated to provide a basis for further work. Based on the evaluation a combination of multiple techniques could be designed and developed.

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