Visual Metaphors for Notification into Virtual Environments

Category: Research

Figure 1: An early prototype shows how the *Door* metaphor could be designed and implemented. The virtual door appears in the virtual environment at the position of the incoming bystander. When the door opens, it activates a video-based pass-through mode, allowing the HMD user to visually perceive the real environment beyond the virtual door.

ABSTRACT

The novel research field of Cross-Reality enables the usage of different stages on the Reality-Virtuality Continuum or to move between them. To facilitate communication between or within these stages, it becomes essential to notify head-mounted display users about ongoing events, distractions, or communication approaches in their current Mixed Reality application. These notifications can originate from any other stage of the continuum. In this position paper we explore how visual notifications can be designed to reflect well-known metaphors. We present five initial concepts for notification metaphors, focusing on seamlessly integrating the notification in the Mixed Reality experience to achieve a high plausibility. An initial implementation shows how such notification could look like.

Index Terms: Human-centered computing—Mixed / augmented reality; Human-centered computing—Virtual reality;

1 INTRODUCTION

Recent advancements in head-mounted display (HMD) technology have made it possible to experience all stages of Milgram's Reality-Virtuality Continuum (RVC) [21] within a single display. Cross-reality (CR) applications now enable users to seamlessly navigate [26] and interact across multiple stages [5] of the RVC, leveraging the advantages offered by each stage. In order to facilitate communication between or within these stages, it becomes necessary to notify the HMD user about ongoing events, distractions, or communication approaches within their current Mixed Reality (MR) experience. Interruptions can occur at any position along the continuum and can be initiated or caused by any involved stage. For instance, a Virtual Reality (VR) user may be informed about a person entering the physical space, or an Augmented Reality (AR) user may receive notification about an upcoming VR meeting.

However, immersive media, such as AR, VR, or CR in general, create an illusion that virtual content is perceived as if it were real. To achieve this sense of realism, both Place Illusion and Plausibility Illusion are necessary [30]. Slater et al. [31] recently emphasised that plausibility is particularly crucial and challenging for creating a believable MR experience that responds in a manner we would expect from reality.

If the MR application already provides a high level of Place Illusion and Plausibility Illusion, notifications should not disrupt the plausibility, as regaining it can be difficult. Designing notifications requires the same level of deliberate attention as the application itself to consistently maintain high plausibility. We believe that incorporating familiar metaphors [9] from the real world into the design of notifications is important to ensure a high level of plausibility.

In this position paper, we explore how visual notifications can be designed to reflect real-world metaphors and provide initial concepts. Particularly when using an HMD, the visual channel can be fully controlled within the field of view, unlike mobile AR or desktop applications. Therefore, the visual design can significantly influence the perception of the notification metaphor.

2 RELATED WORK

In the following section, we provide an initial overview of related work in the area of visual notifications. We have identified three important aspects that should be considered when designing these visual notifications.

2.1 Notification Source

Most of the current work focuses on integration of human bystanders. While reviewing related work in this area we identified 13 publications discussing different techniques to display other humans in the virtual environment [1, 4, 9, 10, 15, 18, 20, 22, 24, 25, 29, 32, 33], while only seven showed methods of integrating moving or stationary objects like smartphones or obstacles [3, 7, 8, 12, 14, 22, 33], and none focusing on animals like cats or dogs but is an important topic for pet owners and needs to be address in future work [23]. Others did not focus on any specific notification source and showed different types of notification suited for any source [11, 16, 19, 28, 34]. However some types of notification can be used more broadly than others, as it is possible to display any interruption as text message whereas showing photorealistic avatars are more suited for displaying living beings.

2.2 Degree of Notification

Notifications can vary in their degree of interruption and intrusiveness, ranging from low to high levels. Generally, notifications with higher noticeability tend to be more intrusive, resulting in a higher degree of notification. Mansour et al. found that simple text notifications are easily noticed and prominent but can also disrupt the overall user experience [18]. On the other hand, a simple attention marker is less intrusive, leading to a lower degree of notification. Rzayev et al. recommended utilising fixed text notifications for notifications that are intended to be intrusive, highly noticeable, but also potentially disturbing [28]. On the other hand, In-Situ notifications

were suggested for situations where a lower degree of notification is desired. Ghosh et al. also reached a similar conclusion, emphasising that delivering notifications as a real-world connection to dedicated objects is a less intrusive approach, resulting in a lower degree of notification [9].

2.3 Type of Visual Notification

Generally there are three main channels to indicate notifications. Audio cues are well suited for guiding the user's attention to the notification source [27]. In contrast haptic feedback can be difficult to interpret by the user [9]. The visual channel can be fully controlled within the HMDs field of view during usage, significantly influencing the perception of the notification. Therefore we focus mainly on different visual notifications types in the following section.

Avatars and pass-trough for bystander awareness: A broad range of previous work focused on visualising the human bystander as avatar, ranging from simple generic avatars (e.g. visualised by a sphere [10]) to more realistic approaches (e.g. 3D scan of the person [25]). Studies typically yielded high results for keeping the Plausibility Illusion intact with using photo-realistic avatars. Using generic avatars however resulted in similar high awareness values but significantly lower plausibility values [10]. Others did not directly ask participants for their perception on Plausibility Illusion, but used a presence questionnaire. O'Hagan et al. found that higher amounts of reality decreased the involvement in the VR environment. Text notifications however did not decrease presence while being disruptive and frustrating for users [25]. A study by McGill et al. showed that inferring the presence of reality significantly raises presence and user preference in comparison to baseline scenarios (lifting the HMD) [19].

There are different ways of representing bystanders as avatars. The most common one is to show a model or 3D scan of a person [10, 11, 18, 19, 25]. To discriminate bystanders from other (virtual) humans, outlines around the character are used [10]. Others wanted to minimise the intrusion by the bystander and only showed a transparent version of the avatar [19, 20].

Instead of modelling avatars representing bystanders, pass-through mode can be used for bystander awareness. There are two types of pass-through, beginning with partial pass-through (only showing a small window to the real world) [32] to using full pass-through (filling the display with the window to the world) [25]. Using pass-through mode for different objects (laptops, smartphones, bystanders) raises presence and safety perception for users [33]. Participants of the BANS study felt more secure having identifiable information like identity and location over the bystander. However pass-through mode is perceived as too interrupting compared to less intrusive methods like 3D avatars. [18]. The comparison of 3D models and pass-through for objects (in a car) resulted in a similar presence and usability score [16].

In addition to visual cues, audio notifications can be used to identify bystanders. In visually demanding environments, it can be difficult for users to recognise visual cues and therefore other forms of notifications can be used additionally [2]. To direct the user to looking in a certain direction another option is to use lights or other cues. These can also be included into the scene (e.g. light up a already existing lamp) [27].

Text notifications: The most simple notification type is using text notifications. They can be used in bystander awareness [25] [18] or to get general information of the outside world [11]. Notifications inform the user of changes in the real world, but lack the information of who or what exactly is going on and where the change happened. Notifications can again be categorised by their position in the virtual world. The three placement options are using a virtual display already built in the environment, binding the notifications to the position of the controller or letting it float in front of the users view. The placement of the notification has direct effects on perception of the notifications and their disruptiveness. More notifications were missed when shown on moveable displays especially in environments needing a high level of concentration. Notifications bound to the controller were perceived as more disruptive [11].

Other methods of awareness providing a little bit more information than notifications but still less than pass-through or avatars are using a radar representation (giving a relative position based on the users position) [18]. In comparison to showing an avatar the radar view was perceived as being more distracting, because users had to move their focus to the edge of the display to see the radar [15]. Another option is to use coloured spotlights to hint to the general position of a bystander. Medeiros et al. showed that using colours as notification is a good compromise between presence, noticability and disruption. They also used an arrow pointing in the direction of a bystander which yielded similar results than the lighting [20]. Kanamori et al. experimented with blending in real world obstacles by creating a point cloud, showing outlines of the objects and showing VR objects representing objects in the real world. The first two option reduced presence probably because of how much of the VR world is overlaid with real world information. Showing VR objects kept the presence intact compared to the baseline condition [14].

There are already numerous notification methods available; however, none of them are specifically designed to maintain the Plausibility Illusion or consider how different notifications may impact it.

3 Concept for Notification Metaphors

In the following, we present five initial conceptual ideas to notify HMD users in their current MR experience about ongoing events from other stages of the RVC. Our concepts build upon existing work and extend them with visual metaphors. The notification method employed utilises context-sensitive metaphors to maintain a high level of plausibility within the MR experience. Matching audio and haptic cues can support these visual metaphors to increase plausibility. When it comes to the source of notification, we differentiate between direct user notifications (e.g., someone entering the room, bystander, remote person) and indirect abstract notifications (e.g., smartphone ringing).

3.1 User Notification: Door

The *Door* notification expands on the idea of a viewport or lens into the real environment by simulating the behaviour of a real door. The notification replicates a genuine and recognisable behaviour linked to a door, encompassing actions such as knocking, entering the room through the door, and subsequently drawing the attention of the occupant. Its purpose is to inform the HMD user that someone is entering the same shared space. Nonetheless, it should be noted that this form of notification deviates from a pure awareness notification, as it implies that the person in the room necessitates the attention of the HMD user.

Visual design: To achieve a coherent visual representation, the virtual door should be positioned where the real door is located or where the incoming person seeks attention. For high plausibility, the virtual door should correspond to the graphic style and genre of the specific application and virtual environment (e.g., sci-fi, medieval, conference room). If there is no door in the current scene, a comprehensible process must be established to create it, such as morphing, materialising, or assembling.

By opening the door, the pass-through mode of the HMD is enabled, allowing the HMD user to perceive the real environment behind the opened door. The *Door* acts as a portal and connects the virtual and physical world. The HMD user can now interact with the incoming person through the door. If the incoming person continues further into the virtual space intended for the HMD user, they must continue to be represented. The representation of the incoming person depends on the specific virtual scenario. Representing the

person as a video stream using Augmented Virtuality (AV) may only be plausible in an equally photorealistic virtual environment, while transitioning to a virtual avatar in a different scenario may be more plausible.

Audio and haptic design: To capture the attention of the HMD user, audio cues that simulate the sound of knocking on the door can be incorporated, accompanied by corresponding controller vibrations. The utilisation of spatial audio enhances the perception of sound location, enabling accurate identification of the incoming person's position. This combination of auditory and haptic stimuli aims to effectively attract the attention of the user towards the door notification.

Implementation: Figure 1 illustrates a potential design and implementation of our *Door* metaphor. In this scenario, the HMD user is in a medieval MR experience, while another individual enters the play area and seeks the attention of the HMD user. A virtual door materialises in the environment at the exact position of the incoming bystander. The door gradually opens, enabling a communication between VR and the real world using AV. Unlike a simple lens or complete see-through, the door emulates the behaviour of a real door within the VR context. As it opens further, it progressively reveals more of the real environment. This design approach maintains the MR experience for the HMD user while providing a plausible interruption that facilitates communication with the real world.

3.2 User Notification: Hologram

Holography, developed by Gabor Denes [6], is a technique that allows for the recording and subsequent reconstruction of a wavefront. Unlike traditional photography, holography captures both the intensity and phase information of the wavefront. A hologram is a photographic record created using holographic techniques. When reconstructed with coherent light, it gives the impression of objects suspended in space, creating a fully three-dimensional experience.

In contrast to the scientific approach, we use the concept of a *Hologram* as popularised in sci-fi movies and video games. Within this context, a hologram is known as a three-dimensional representation or projection of a remote user. By incorporating holograms, the notification and interaction of a remote user within the existing virtual environment can be facilitated. This approach offers rich and engaging visual context by enabling depth perception and conveying non-verbal cues and body language, thereby enhancing a sense of realistic communication and plausibility.

Visual design: The *Hologram* metaphor expands the notion of a fully virtual avatar representation by integrating a recognisable visual effect and technique commonly employed in films and games (see Figure 2). Holographic content is typically characterised by vibrant and saturated colours, radiating light rays, and incorporates scan lines or grids that give the impression of movement or scrolling across the holographic image. This contributes to a futuristic and high-tech visual aesthetic often associated with light field or volumetric displays. Holograms often possess semi-transparent appearance, allowing users to partially see through them. The specific representation of a person within a hologram depends on the available technology and can range from photorealistic 3D models to approximate point clouds. Similar to the door metaphor, the appropriateness of a plausible representation depends on the visual style of the surrounding environment, where photorealistic images may not always be suitable. The size of the holographic representation can vary, ranging from life-sized to miniature. Unlike the door metaphor, the holographic representation is not restricted to a specific real-world location and can be positioned flexibly within the virtual scene. The *Hologram* is applicable in a fully virtual environment as well as in AR.

Audio and haptic design: The audio and haptic feedback should complement and enhance the visual elements of the *Hologram*, by incorporating believable and futuristic sounds. An effective approach could involve the utilisation of spatial audio cues that synchronise with the initiation of the holographic transmission, accompanied by haptic feedback through vibrating controllers.

Figure 2: (left) Hologram representation in Star Wars [17] for remote communication. (right) Visual avatar representation as a Hologram in the video game Halo Infinite [13].

3.3 Abstract Notification: Display

In virtual environments, text, images, or video notifications are commonly presented as floating overlays. However, to enhance the impression of realism, it is recommended to integrate these notifications into the virtual environment or establish an intuitive connection with the user. This can be accomplished by employing a display metaphor, where the notification appears on a device that resembles those used in everyday life. If displays or monitors are already present within the virtual environment, text notifications from a smartphone or video calls can be exhibited on these screens, creating a more convincing analogy. Alternatively, AV can be utilised to overlay the virtual display with the actual display, offering a real-world view on the screen. Similar to the door metaphor, the visual design of these notifications can vary depending on the current MR experience, ranging from traditional CRT monitors to futuristic sci-fi displays.

3.4 Abstract Notification: Wearable

Communication alerts can be presented using a wearable metaphor, where the information is shown on a device worn on the body, such as smartwatches. The notification content can be fully displayed in a virtual manner on the user's tracked hands or controllers [28], or by utilising the video pass-through capabilities of HMDs to provide a real-world video stream from the actual watch. Consequently, only a small portion of the user's field of view is excluded from the current MR experience. The majority of smartwatches are capable of detecting a hand-raising gesture to activate the display and can offer haptic feedback, which can also be integrated into the smartwatch metaphor. All of these elements contribute to enhancing plausibility when conveying text, images, or video notifications.

3.5 Abstract Notification: Message Delivery

Brief messages or alarm clock notifications can be exhibited utilising a metaphorical approach to message delivery, such as a message in a bottle, a carrier pigeon, or post-it notes. The choice of message delivery techniques depends on the desired setting that the MR experience should reflect, to provide high plausibility. According to the significance of the notification, the message carrier can be more visually prominent or rather subtle integrated in the MR experience.

4 Conclusion and Future Work

This position paper presents our initial ideas and concepts for integrating visual metaphors to deliver plausible notifications in virtual environments using various stages of the RVC. We have provided detailed explanations for five specific ideas to offer an understanding of how these notifications could be designed. Additionally, we

present an early prototype mock-up for one of the techniques to showcase its potential implementation using AV.

The design and implementation details of delivering plausible notifications in virtual environments depend on several factors:

- **Available Technology:** The specific technological capabilities, such as video pass-through mode, tracking capabilities, and external application integration, determine how the notifications can be effectively incorporated.
- **Degree of Notification:** The level or importance of the notification influences its presentation and prominence within the virtual environment.
- **Setting of the Experience:** The specific context or environment of the virtual experience plays a role in determining the design and delivery of the notifications.
- **RVC stage:** Depending on the stage along the continuum, different approaches may be better suitable for integrating the notifications.
- **Type of Notification Source:** The nature and source of the notifications, whether it is text, images, or other forms, also impact their implementation within the virtual environment.

Considering these factors, the actual implementation of plausible notifications metaphors in virtual environments can be tailored to optimise the user experience and communication between or within different stages of the RVC.

However, there are situations where a metaphor is not necessary, such as a fire alarm or other notifications about hazardous situations. In these cases, the focus should be on safety, prioritising immediate activation of the see-through mode, if available, and displaying crucial information within the user's field of view.

Further research is required to assess the proposed concepts through controlled user studies and explore methods for facilitating communication between stages of the RVC or within a single stage after notifying the HMD user. We would like to open the topic for a joint discussion and invite other researchers to find alternative metaphors for plausible notifications in the area of Cross-Reality.

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