Immersive Notification Framework: Adaptive & Plausible Notifications in Virtual Reality

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Abstract
Notifications in everyday virtual reality (VR) applications are currently realized by displaying generic pop-ups within the immersive virtual environment (IVE) containing the message of the sender. However, this approach tends to break the immersion of the user. In order to preserve the immersion and the suspension of disbelief, we propose to adapt the method of notification to the current situation of the user in the IVE and the messages' priority. We propose the concept of adaptive and immersive notifications in VR and introduce an open-source framework which implements our approach. The framework aims to serve as an easy-to-extend code base for developers of everyday VR applications. As an example, we implemented a messaging application that can be used by a non-immersed person to send text messages to an immersed user. We describe the concept and our open-source framework and discuss ideas for future work.

Author Keywords
Virtual Reality; Virtual Environments; User Notification; Presence; Immersion; Framework.

ACM Classification Keywords
H.5.1 [Information interfaces and presentation (e.g., HCI)]: Multimedia Information Systems - Artificial, augmented and virtual realities

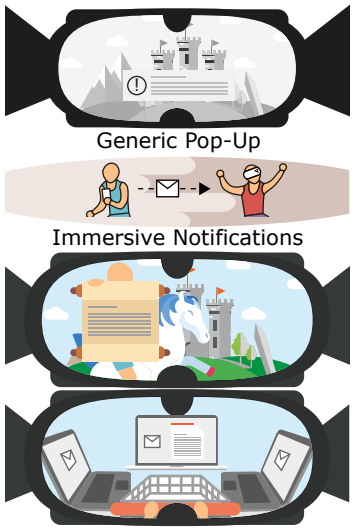

Figure 1: Immersive notifications in VR: An immersed user receives a message sent by a non-immersed person. Instead of being disturbed by a generic pop-up displaying the information, a mounted messenger approaches the user in the medieval VR experience and hands her a letter with the text. When shopping in a virtual department store, however, the message might be displayed on the screens exhibited in the electronics department of the VR store.

Introduction

Virtual Reality (VR) is currently evolving into an everyday technology with the potential to be used in many different fields such as education, training, therapy, and entertainment [1]. Applications simulating immersive virtual environments (IVEs) are becoming increasingly sophisticated and interactive. Core concepts therein are *immersion* and the feeling of *presence*, which describe the acceptance of a user's state of mind relating the virtual world as the one actually being and acting in. Presence consists of two factors known as *place illusion* and *plausibility illusion*. During the existence of both, users show realistic responses to the IVE [3]. For an immersive experience, the VR application and system are supposed to stimulate the user's senses in a continuous and plausible way with stimuli from the IVE. This preserves immersion and allows the user to experience the IVE without being reminded of the physical world, which could impair the sense of presence.

While being immersed, however, non-immersed people in the real surroundings of the user might want to get in contact with the immersed user, or the VR user might need to be made aware of specific notifications, e.g. from a smartphone or the environment. In these cases, information originating from a real-world event is supposed to be presented in a conceptually different world – inside the IVE.

To notify the VR user, a non-immersed person might nudge the user and talk to her. Being very interruptive, this severely distracts the immersed user from the IVE, causing breaks in their sense of presence. To prevent this, an alternative approach is to send a message via a software application, e.g. on the smartphone, to the immersed user. Today's state-of-the-art systems already show support for this by displaying the received message as a common virtual notification overlay, e.g. a generic pop-up with the notification text as sketched in Figure 1, in the user's field of view. This approach is not optimal with regard to the user's sense of presence, as the sudden appearance of a generic text pop-up is in many contexts unexpected, unrealistic and inappropriate. As a result, the plausibility of the IVE – and thus a crucial component of presence – might suffer.

In this paper, we introduce an alternative concept to notify an immersed user of real-world information. To preserve the immersive experience in the IVE, it seems sensible that a VR user relaxing on a virtual beach should be notified in a different manner than a user fully engaged in an action game. Thus, we propose a general framework that allows for an easy inclusion of adaptive notifications in VR applications. It takes into account the importance of the incoming information, the current situation of the immersed user in the IVE and a set of immersive notification animations defined by the application developers to trigger the notification that suits the virtual situation best. Instead of generic pop-ups, these immersive notifications are supposed to be scripted events in the virtual environment that match the virtual context and represent realistic, appropriate and plausible ways of notification in the context of the IVE. We present a first implementation of the notification framework which serves as a basis for future integration in VR applications and which can be extended by the community. Moreover, we demonstrate an actual instantiation of the concept by discussing a VR messaging system using the framework. To conclude, we summarize directions for future work and for the evaluation of the concept.

Related Work

This section discusses work related to our approach concerning the concept of presence and user notification.

Immersion & Presence
As central aspects of VR experiences, *presence* depicts the user's feeling of being and acting inside the IVE and *immersion* expresses how well the system stimulates the user's senses. Being a property of the entire VR system, immersion is described from a technical perspective, while presence is a function of the user and the utilized system's immersion [1, 5]. Immersion allows a user to experience presence but does not guarantee it, as the actual feeling of presence also depends on the user's psychological state and may vary over time. In certain circumstances, e.g. when a person not part of the virtual world speaks to an immersed user, *breaks in presence* can occur that end a user's feeling of presence, which are to be avoided [1, 4].

Previous research identified two key aspects crucial for the feeling of presence: *place illusion* and *plausibility illusion* [3]. Our concept introduced here aims to prevent breaks in presence by maintaining the plausibility of the IVE when presenting real-world information. In contrast to naive approaches, e.g. directly interacting with the VR user from outside the IVE or showing generic pop-up messages, we aim to adapt information presentation to the virtual context.

User Notification
Appropriate notification of users is a requirement of many real-world systems and has been extensively studied in the past [2]. Our conceptual approach for seamless user notification in IVEs is related to real-world approaches known as ambient notifications [6]. This concept has been a focus of past research and utilizes elements embedded in the user's environment, such as lights or sounds [6], to guide a user's attention and to provide information in an unobtrusive way. Some commercial VR systems and applications, such as the HTC Vive[1] and the Samsung Gear VR[2], implement features which allow an immersed user to receive specific notifications, e.g. text messages, phone calls, calendar events, or notifications from various other applications supported through additional software[3]. However, they typically rely on the naive approach of presenting a generic pop-up element to the user. The appearance of the message is not adapted, nor is the form of information presentation tailored to the user's current situation in the IVE. This can lead to frustration and increases the risk of breaks in presence.

Some research efforts on immersive notifications for VR and corresponding frameworks for application developers exist[4]. However, to the best of our knowledge, no scientific publications nor any open-source frameworks exist that refrain from using generic pop-up overlays and concentrate on immersive user notifications able to adapt to the user's virtual context as proposed in this work.

Immersive Notification Framework

As users immersed in different VR applications can experience fundamentally different IVEs, generic solutions to provide notifications are suboptimal. In the following, we propose to include the design of immersive notifications in the development process of VR applications.

Concept
We propose that immersive applications should implement notification events that fit the virtual world experienced by the user. When receiving a message while being immersed in an application with, for example, a medieval setting, the virtual avatar of a mounted messenger could approach the user to hand her a letter containing the message sent by a

[1] https://www.vive.com/
[2] http://www.samsung.com/global/galaxy/gear-vr/
[3] https://github.com/ThomasGaubert/zephyr
[4] http://nishantdp.com/projects/NotifiVR.html

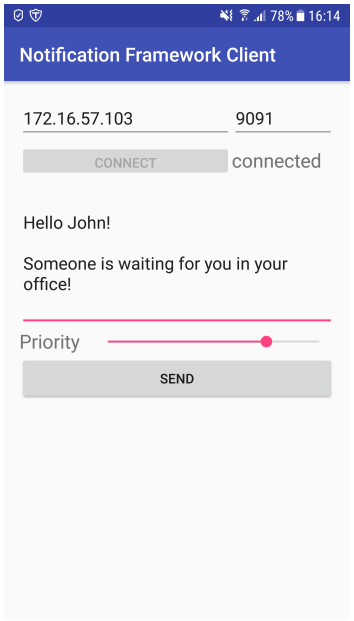

Figure 2: The accompanying Android app. Non-immersed users can send messages with a custom priority to the immersed user over the network.

non-immersed person. In a sci-fi game, the mounted messenger could be replaced by a futuristic communication drone. In contrast to a suddenly appearing generic pop-up, we hypothesize that such scripted animations can maintain the plausibility of the IVE and prevent a break in presence – a hypothesis to be investigated in our future evaluation.

Aside from an adaptation to the general setting of the IVE, we additionally propose to adapt notifications to the user's virtual situation and current psychological state. Context information about the user might, for example, include stress level or concentration, and immersive notifications will need to adjust to that as well. As an example, an obtrusive but plausible event might be necessary to immersively guide the user's attention to an important message while the user plays an engaging game in the IVE. Here, a virtual power blackout could be a way to force the user to pause the gameplay and reactivate a virtual power generator on which the user finds the message sent to her. In contrast, while relaxing on a virtual beach, it might suffice to let a virtual bird tweet the important message from the sky. The information about the context of the user in the IVE, e.g. experienced stress, could either be deduced from the user's current progress in the VR application, i.e. the currently experienced level or room, or could be gathered with appropriate hardware monitoring physiological signs.

Implementation

Our open-source framework is implemented for the Unity engine and is publicly available on GitHub[5]. The involved components are depicted in Figure 3. To showcase a VR messaging app scenario, the package comes with a simple Android application, depicted in Figure 2, that allows non-immersed users to send a text message over the network. Before sending the message, the user can assign a custom

[5] https://github.com/AndreZenner/notifications-framework

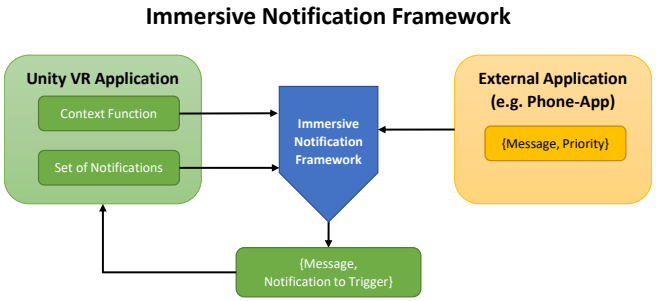

Figure 3: Conceptual architecture of the framework.

priority p ranging from 0 (= lowest) to 1 (= highest). The message is sent to the IP address of the immersed user's PC running the Unity VR application with the framework.

The second component, depicted in green in Figure 3, is the VR application. The application provides a *Context* function that outputs a context rating c between 0 (= calm context) and 1 (= engaging context), summarizing the current situation of the immersed user. In addition, developers can specify the amount of different levels of notification N considered in their application in the third component, the central *Notifications Manager*. For example, a setting of $N = 3$ might represent the 3 levels *unobtrusive*, *medium* and *obtrusive*. As a next step, developers link their implementations of immersive notification animations to the *Notifications Manager* component. For each of the N levels of notification, multiple animations can be defined and linked. The specified *Selection Method* then defines how the framework chooses between those of the same level, e.g. randomly or sequentially. Given an incoming message with priority p and the user's virtual context information c, a decision function chooses the actual level of notification to trigger. Our adaptive implementation assumes that for a specific message priority, calm contexts require less

Figure 4: Overview of the virtual supermarket scene.

Figure 5: *Level 0 - Unobtrusive:* The incoming message is displayed on a public display in the virtual supermarket.

obtrusive notifications than engaging virtual contexts, and that increased priority leads to more obtrusive notifications in the IVE. It thus computes the final notification rating as $r = (p + c)/2$ with $r \in [0, 1]$. The rating r is used to decide the notification level to trigger the correct animation. For this, the index $i \in [0, 1, ..., N - 1]$ of the notification level to trigger is computed as $i = \lfloor r \cdot N \rfloor$ (and $i = N-1$ for $r = 1$). When triggering, the framework passes the message to the chosen animation in order to immersively display it.

Example
To test our concept, we used the framework to integrate the described messaging system in a VR game for future evaluation. The game requires the user to collect items in a small supermarket, which is shown in Figure 4. As the user is only allowed to collect specific items for a limited amount of time, we can control the difficulty of the game, and consider this as the stress or context of the user. Here, we use 3 levels of notification (unobtrusive, medium and obtrusive), as depicted in Figure 5, Figure 6 and Figure 7, to adaptively notify the user.

Discussion

The introduced framework provides a starting point for future study on immersive notifications. We aim to study how context-aware and immersive presentation of real-world information can maintain plausibility to prevent breaks in presence. As plausibility was found to be a crucial component for presence in IVEs [3], future investigations will consider lessons learned from notification research in real environments to study their effectiveness in IVEs. Based on our framework and the supporting idea of adaptive and immersive VR notifications, we see several directions to continue from here.

Evaluation of the Concept & Framework
As a next step, we will perform a user study investigating our hypothesis that generic pop-up overlays in VR are prone to inducing breaks in presence. Comparing the current state of the art with our adaptive approach, we aim to evaluate the influence of immersive context-adapted notifications in VR on the experienced presence. For this evaluation, we aim to use the supermarket game introduced in the previous section and consider appropriate notifications.

Extension of the Concept & Framework
Besides receiving real-world text notifications, the framework offers potential for further extension. An important feature we consider is the ability for the VR user to respond to incoming messages. Additionally, a forwarding system for application notifications from a smartphone and the inclusion of direct communication events, such as phone calls or doorbells with intercom systems, introduce very interesting potential scenarios to explore. In these events, users could talk to virtual avatars of the person calling or ringing, embedded in the virtual setting and story. Moreover, everyday events occurring in the user's real surroundings could be translated to the virtual context. For example, the beeping of a timer in the user's kitchen could trigger a virtual fire alarm to remind the user. Furthermore, the physical presence of persons or pets could be visualized with virtual avatars or objects, matching the aesthetics of the IVE.

Guidelines for Immersive & Adaptive Notifications in IVEs
The introduced concept requires VR developers to think of suitable notification animations that fit their IVE and different contexts the user might be in, starting in the design stage. Integrating the framework in different VR applications covering various domains (e.g. games, education, architecture, simulation, training, or therapy) and various scenarios (e.g. IVEs that are contemporary, medieval, ancient, futuris-

Figure 6: *Level 1 - Medium:* Additionally to Level 0, the lights are dimmed while spots point to the display.

Figure 7: *Level 2 - Obtrusive:* Finally, a cage is added to block access to the shelves.

tic, or fantastic) allows for the investigation of different types of immersive notifications. Systematic research in this direction, informed by past results on mobile, desktop, wearable and ambient notification in real environments, could lead to the derivation of general guidelines. These will help developers to find, design and integrate appropriate notifications in future VR applications more easily and might lead to a higher prominence of the concept in general.

Conclusion

We introduced our approach of immersive notifications for VR. Our method is motivated by the unsatisfying state-of-the-art approach of displaying generic notification pop-ups that do not adapt to the experienced IVE, implemented in current VR systems. To maintain the feeling of presence, our method aims to preserve plausibility when providing the user with real-world information. We propose to notify immersed users with plausible animations and interactions in the IVE, that adapt to i) the general setting of the virtual world (i.e. aesthetics, story, environment) and ii) the current context of the immersed user (i.e. how engaging the user's virtual situation is). We provide the concept of a framework to include immersive notifications of incoming real-world messages in VR applications. In addition, we describe our open-source implementation of it, available for the Unity engine, exemplarily showcase a basic VR messaging system based on it, and discuss several examples of plausible and adaptive VR notifications. Finally, we outline starting points for follow-up research to evaluate our method, provide ideas of meaningful future framework extensions and discuss where further research on this topic can lead.

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