Personalized Personal Spaces for Virtual Reality

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Figure 1: Left: scary image from a 360 degree video in virtual reality (image: MPC, moving-picture.com). The masked head is only a few centimeters away from the viewer, causing discomfort. Right: different personal spaces (image: CC BY-SA 3.0, Wikimedia Commons).

Abstract

An important criterion for virtual reality experiences is that they are very immersive. The person inside the head-mounted display feels like really being in the virtual environment. While this can be a very pleasant experience, the opposite can happen as well. The concepts of personal spaces and people or unfriendly avatars entering them, can lead to the same discomfort as if it would happen in real life. In this work, we propose to define multi-level artificial barriers for other avatars and objects, respecting the personal spaces as defined by users. We apply this to both interactive rendered environments and as much as possible also to 360 degree photo and video content.

Index Terms: Social and professional topics—User characteristics——

1 Introduction

With the success of virtual reality in the consumer market, there are many immersive and personal experiences that are enabled by modern wide-angle head-mounted displays. These are either interactive, real-time rendered games and applications or pre-recorded 360 degree photos and videos. Because the viewer of such immersive media feels like really being inside what is shown, this has other effects that can become troublesome: the same as in real life, the concept of personal space applies to virtual reality experiences. Its violation can lead to an invading and undesired experience.

In this work, our contribution is:

- a multi-level specification for the user regarding invasion of different personal spaces from different entities
- using a virtual environment to calibrate setting the personal space preferences
- defining potential reactions from games, applications and for watching 360 degree photos and videos

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2 Related Work

Grosser [4], an artist, described the distances from drawing humans in portraits and divided them into intimate, personal and social spaces. Hediger [6] applied that concept to animals keeping a social distance between them. Hall [5] made further differentiation into a personal distance zone where smells and touch can be exchanged and a social distance zone without these features. He defined four spaces (see Figure 1 right): intimate, personal, social and public. Amaoka et al. [1] used the concept of personal spaces on videos of people and deducted through the distance of the people to each other what kind of relation they have. While the previously mentioned studies have been done in the real world, there has also been analysis confirming that the concept of personal spaces applies to virtual reality [2] [8].

In consumer virtual reality, the application "BigScreen"[1] added in 2016 a virtual space bubble around the user to avoid violation of the personal space. SteamVR[2] added such a feature in 2017 to their social platform SteamVR Home and allowed users to set a size for this bubble. Compared to the previous work, we will enhance this concept to a finer multi-level setting for different personal spaces and different entities.

3 Defining Personal Spaces

For this work, we will use the four spaces from Hall [5]:

- intimate space: within 0.45 meters to the user
- personal space: 0.45 to 1.2 meters
- social space: 1.2 to 3.7 meters
- public space: above 3.7 meters

Users might have different preferences regarding the potential invasion of personal spaces. Some players of horror games might want to be fully scared, while others still want to play the same game, but at a less intense level. Therefore, we propose to let the user choose the values of the following matrix. First, we categorize static objects, which are not alive. This can be walls, columns, tables and so on. Dynamic objects, but not alive would be items that might

[1] bigscreenvr.com

[2] steamvr.com

be thrown towards the user like a ball or a bullet from a gunshot. We differentiate the avatars into friendly ones, which are trying to help the user progressing the game or might even be intimately close real persons as avatars. Neutral avatars will not harm the user, but also not help progressing the game in any way. This could be a simulated crowd at a big market place. The unfriendly avatars intend to virtually harm the user and are an obstacle for reaching a goal, e.g. an enemy blocking the path to a certain goal. The user is asked to choose for these five categories which personal spaces are allowed to be invaded by them and displayed by the rendering engine. We excluded setting options for the public space as this should be accessible for all objects to guarantee basic game logic. In the social space, we excluded settings for inanimate objects. This allows the user to always get closer to a wall or table within the range of 1.2 to 3.7 meters, otherwise the exploration of the virtual world would be too limited. Once an inner space is enabled to be entered, this automatically results in the outer ones enabled as well, e.g. if friendly avatars are allowed to enter the intimate space, they need to be able to enter the personal and social space as well.

	static objects, not alive	dynamic objects, not alive	friendly avatars	neutral avatars	unfriendly avatars
intimate	✓	✗	✓	✗	✗
personal	✓	✓	✓	✓	✗
social	-	-	✓	✓	✓

Figure 2: Example matrix for the user deciding what kind of object or avatar is allowed in which space.

4 Setting Personal Space Preferences

As it might be hard to guess the distances of the different spaces while filling out the matrix, we propose an interactive, fully virtual environment to configure this. For example, an unfriendly avatar slowly approaches the user from a larger distance. The user signals with buttons, voice or other interaction once he starts to feel uncomfortable. The enemy stops moving. The player can still push the avatar back or closer through input controls until the tweaked distance is satisfying. This value is then used as limit of the invasion of the personal space for this category of avatar.

5 Respecting Personal Spaces

Now that the user has indicated the desire towards which objects and avatars are allowed to be in which spaces, these settings need to be followed by the game and application engine. We define individual space bubbles inside the engine for the chosen settings in the matrix. The engine needs to respect this when planning on where to move objects and is only allowed to draw certain objects and avatars within the accepted personal space settings. This will have impact on game play. If an unarmed enemy would not be allowed to come within the 3.7 meters of the social space, the enemy could not inflict damage. The engine would need to take care of that and modify these avatars with some way of causing damage across that distance, e.g. equipping them with stones to throw at the user. If the user walks towards an avatar that is required to keep its distance, the distance of the bubble could be briefly violated. The engine has to take care of signalling the invading avatar to take a course outside of the bubble. Objects thrown at the user or a bullet flying to the user, which would count as dynamic, not alive object, could be required to violate certain spaces to be effective. As the user desired that this space shall not to be violated by these objects, we suggest modifying the near clipping plane for rendering these objects, in order to cull them away once they are displayed too close. That way, the invasion of the personal space would not be visually perceived, but the game engine can still calculate the effect and count a bullet as hit and decrease health.

For 360 degree photos and videos, the situation is different. Images have been already recorded and are played back. There is no game engine that can command any of the pre-recorded actors to keep more distance. We propose having an analysis on the depth of the displayed objects. Specifically, in stereo videos, depth estimates are fairly easy to calculate [7]. If any area in the 360 degree content is so close that it violates our personal space, we decrease the perceived field of view of the displayed video: while the image is used like before, a strong vignetting filter is applied which fades content further away from the screen center to black. This lowers the immersion and therefore the impact and plausibility of feeling that the user's personal space has been invaded. A method like this has been used before to reduce motion sickness [3]. In order to have a smooth transition when lowering the displayed field of view, we propose to look several frames ahead to detect objects too close within the personal space. Having that knowledge, the displayed field of view can decrease slowly and continuously across these frames to avoid fully disrupting the immersion. The same applies for prediction of where the user might look next. If there is a turn of 180 degrees where a scary figure in close proximity will be seen, we can use the continuous data from the head orientation to predict that we need to lower the field of view soon and can smoothly start doing that.

While it is beneficial to set the matrix on which object and avatar can invade which space for a specific game or application, this becomes most valuable if a global profile exists which can be used across different machines and head-mounted displays. We propose to save the settings of such a matrix in common virtual reality launchers, e.g. stored in the SteamVR[3] or Oculus Home[4] profile.

6 Conclusion

In this work, we have shown multi-level options for a detailed selection of which kind of objects and avatars should be able to move into which personal spaces of the user. This allows users to scale down the undesired effects of virtual reality experiences, where personal space is invaded and users feel discomfort and might stop the experience. We suggested using a virtual environment to configure the different personal spaces interactively. We discussed ways of how this can be implemented in game engines and how it can be applied to displaying pre-recorded 360 degree content in virtual reality.

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[3] steamvr.com

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