Utilizing Immersive Virtual Reality in Everyday Work

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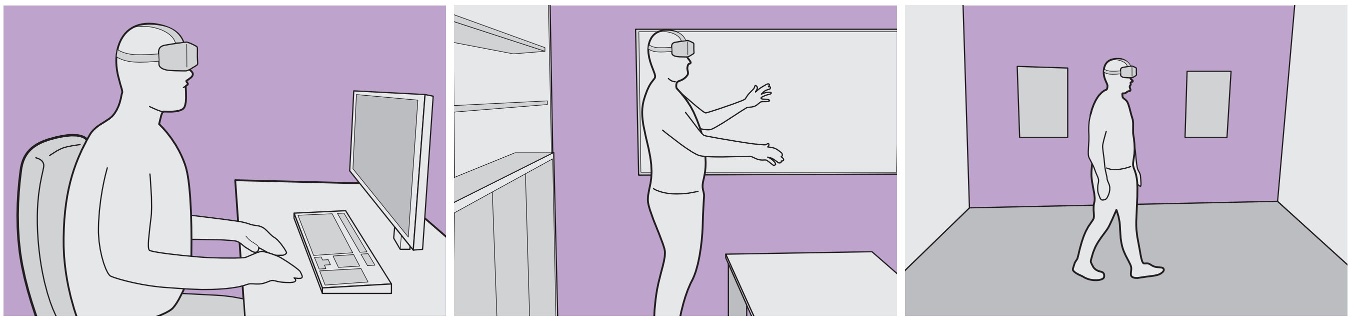

Figure 1: An illustration of the three scenarios discussed in this paper. In the sitting scenario (left), the user is assumed to be sitting at a desk, unable to rotate their body. In the standing scenario (center) the user is standing in a fixed position, being able to rotate but not walk. In the walking scenario (right) the user is able to walk freely in a room-sized area.

Abstract

Applications of Virtual Reality (VR) have been repeatedly explored with the goal to improve the data analysis process of users from different application domains, such as architecture and simulation sciences. Unfortunately, making VR available in professional application scenarios or even using it on a regular basis has proven to be challenging. We argue that everyday usage environments, such as office spaces, have introduced constraints that critically affect the design of interaction concepts since well-established techniques might be difficult to use. In our opinion, it is crucial to understand the impact of usage scenarios on interaction design, to successfully develop VR applications for everyday use. To substantiate our claim, we define three distinct usage scenarios in this work that primarily differ in the amount of mobility they allow for. We outline each scenario's inherent constraints but also point out opportunities that may be used to design novel, well-suited interaction techniques for different everyday usage environments. In addition, we link each scenario to a concrete application example to clarify its relevance and show how it affects interaction design.

Index Terms: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques

1 Introduction

Fully-immersive Virtual Reality (VR) systems exist for decades. Due to their relatively high cost and operational effort, however, their usage on a daily basis has not yet been commonly established. However, cost-efficient Head-Mounted Displays (HMDs) and tracking hardware, mainly designed for gaming, have opened up numerous possibilities of utilizing immersive VR in the workplace regularly. This widespread, everyday use of VR might become a common scheme in the future, especially given the fact that immersive displays have been shown to outperform their non-immersive counterparts in a variety of task scenarios [3, 9].

The reduction of hardware costs to push the reachability of VR, has been a major concern until now. For example, Ball and Johnsen [1] presented an educational application that allows users to explore the anatomy of the human heart. They focus on the use of low-cost hardware to make their application widely accessible and usable outside a laboratory. However, to reduce the amount of hardware required, they made sacrifices regarding interaction, such as limiting navigation to only one dimension.

A mere reduction of costs and an increase in hardware availability, however, do not suffice to establish VR in everyday work. It must also provide recognizable benefits to the user while not being cumbersome or confusing to use. This becomes even more important, seeing that there are certain tasks that are more difficult to accomplish in VR than on a 2D screen with well-established techniques. Selecting and manipulating objects of different sizes from multiple angles is an example of this, as mentioned by Wang and Lindeman [8]. Their approach to overcome the difficulty of using 3D interaction and 2D interaction simultaneously is the use of a Hybrid Virtual Environment (HVE). By using a non-occlusive HMD, the user is able to perceive the Virtual Environment (VE) as well as a tablet device, which is mounted on the user's arm. The VE and the interface on the tablet are coordinated, so interactions that are difficult to accomplish in VR can be performed using the tablet interface. While this is an elegant solution in terms of input techniques, it probably comes at the cost of immersion, as the real world is not completely blocked out.

Another important factor affecting everyday use of VR is that users generally cannot be expected to be located in a carefully prepared environment. Conversely, they are potentially surrounded by various objects and even people who are not using the system. A step towards addressing this issue was made by Simeone et al. [5] under the term Substitutional Reality (SR). The concept behind SR is to match every real world object to a virtual object. While discrepancies between the physical object and its virtual counterpart may occur, users perceive the matching to be more believable if the discrepancy is kept low. This results in a tradeoff between the believability and design freedom for the virtual world. On the other hand, it opens the opportunity to use objects in the users' surroundings as physical props for interacting with the virtual world.

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Table 1: We propose these design guidelines for everyday VR systems based on the discussed scenarios.

	Sitting	Standing	Walking
Immersion	*Design for comfort, not for immersion.* Constraints affect usability the most in this scenario, hence ensuring good usability should be prioritized over obtaining a high-level of immersion.	*Balance comfort and immersion.* Retaining the immersion-related benefits of this scenario over sitting, while considering the larger amount of contraints as compared to walking, is key.	*Design for immersion, not for comfort.* The largest benefit of this scenario is the afforded realism, such that optimizing for immersion should be the design focus.
Travel	*Facilitate navigation with little body movements.* Users are seated and probably reluctant to turn for usability or technical reasons, which must be considered in virtual travel technique design.	*Be mindful of the available degrees of freedom.* Whether movements should be performed physically or via a virtual travel technique depends on the application given the available space.	*Utilize physical movement, use virtual travel only as support.* Realistic physical movements are the strength of this scenario and should be used before resorting to virtual travel techniques.
Environment	*Consider integrating the working environment.* The environment introduces obstacles to the user's movements but can potentially be utilized in interaction design, e.g., as support surface.	*Constantly make user aware of their physical surrounding.* The available space for movements is very limited, such that users need a constant reminder to prevent accidents.	*Make users aware of physical bounds only when necessary.* While the available movement space is fairly large, users will eventually need reminders to prevent leaving it.
Input devices	*Consider the working environment when choosing input devices.* The environment can contain devices that could be used, e.g., keyboards, and might facilitate putting devices down, e.g., desks.	*Consider limitations regarding input devices.* All input devices have to be carried by the user, which affects the number of and type of devices suitable in these scenario.	
Session duration	*Design for many short sessions.* The system should integrate well into the user's usual workflow and thus enable them to switch to and from the VR system as effortlessly as possible.	*Design for few long sessions.* Switching to and from the system requires effort, so the need for switches should be kept minimal.	

The above discussion highlights various efforts that facilitate the everyday use of immersive VR. While the wide availability and reduced costs of VR hardware have already opened up VR to a significantly larger audience, we think that the design of everyday VR experiences still falls short, especially when considering professional applications. Similar to the work by Simeone et al. [5] regarding SR, we argue that the design of VR applications is heavily influenced by its usage scenario. If, for example, a user can be expected to sit during use of an application or to use it in a confined office space, this will most certainly have implications for the interaction design, such as the choice of navigation techniques. Understanding these implications is crucial when designing everyday VR applications.

In an attempt to facilitate an informed design process of such applications, we describe three common usage scenarios in this work. Each usage scenario entails certain limitations, such as space or mobility constraints, but also offers opportunities, which can be utilized during interaction design—similar to what is done in Substitutional Reality. While we do not claim completeness, we imagine this set of scenarios to be a solid starting point to and crucial factor of the successful design of everyday VR experiences. To show how each scenario can influence interaction design, we propose design guidelines and discuss concrete application scenarios.

2 Scenarios

We define three usage scenarios: sitting, standing, and walking (illustrated in Figure 1). The differentiation between these scenarios follows naturally from the amount of mobility that users of a VR system need to have. A differentiation that is similar but less formal can be found on the games platform Steam[1]. The platform provides access to a variety of VR games, that are sorted based on multiple dimensions, one of which is the "Play Area". This dimension has three possible settings: Seated, Standing, and Room-Scale. These settings directly correspond to the usage scenarios described below.

A similar classification is presented by Simeone [4]. They define three types of SR systems based on the scale of the pysical area the user can move in: Desktop SR, Room-Sized SR, and Large-Scale SR. Their Desktop SR system fits our sitting scenario and their Room-Sized SR system fits our walking scenario.

[1] `http://www.steampowered.com`

In this section we give definitions of our scenarios and discuss their impact on interaction design. Based on this discussion, we propose a set of design guidelines for each scenario as presented in Table 1.

2.1 Sitting

An important aspect to consider when designing systems targeted at everyday use is the user's comfort. Most potential users work seated in front of a desk. Requiring them to stand up, or even leave their desk, could create a hurdle that might make using the system unattractive. In addition to that, prolonged usage of a system is more comfortable when seated. Fortunately, for certain applications there is no need to require the user to stand up. An example for this is the analysis of abstract data that has no correspondence to physical space. The realism provided by natural interaction and hence perfect immersion is not required in this case, as realism is not the main focus.

Based on these observations, this usage scenario assumes the user to be seated in front of a desk. Independently of the chair the user is sitting on, they are not assumed to be able to rotate their body. Interactions should be accomplished with as little movement as possible, similar to common office work. While many kinds of one- or two-handed interaction techniques are possible, it is advisable to let the user rest their hands on a table most of the time to make interaction less cumbersome. This makes navigating a VE in this scenario a challenging task; however Zielasko et al. [11] describe five different navigation methods applicable here.

Clearly, in this scenario the possibilities for natural interaction are severely limited, decreasing the amount of immersion that is achievable. However, for applications that do not require a high amount of immersion, sitting provides the highest degree of comfort. Additionally, the desk the user is sitting at provides an opportunity for specialized interaction techniques for this scenario. As an example, the desk surface could be used to provide passive haptic feedback for menus, by aligning their virtual representation with the physical surface. Additionally, the desk surface could serve as a convenient location to place devices for prop-based interaction, allowing for many different, specialized devices. Additional semantics could be given to common objects on the desk via a Desktop SR system.

2.2 Standing

Certain applications might require the user to perceive the VE from a standing position. The dimensions of rooms and objects can be better perceived while standing, as the user can use their own height as a reference. For instance, looking at a life-sized architectural model from a sitting position will not provide the same feeling to the user as if they were standing. In addition, architectural models of rooms might contain objects that would occlude the user's field of view, while seated. However, the physical space at the user's workplace might be limited, so walking around might not be possible, but standing up might still be.

Therefore, this scenario assumes the user to be standing in a fixed position. In this position, they are able to turn around, duck, jump or move any body part as long as they do not leave their position. While this enables many kinds of full-body interactions, natural walking is not possible, however, walking-in-place [6] is. Since the VE might suggest that the space around the user is larger than in reality, special care has to be taken to constantly make them aware of the limited real space.

Even though Simeone [4] does not mention this scenario for SR systems, using SR to incorporate physical objects into the VE is also conceivable. Not only might this help the user to stay within the bounds of the system, but menus might again be provided with passive haptic feedback by utilizing real-world surfaces in the user's surrounding.

2.3 Walking

Walking is the most natural way of navigating a VE [7], and applications that require a very high degree of immersion might not be feasible without it.As an example, when looking at a large, real world object that fits inside a room, being able to walk around it enables the user to develop a solid understanding of its dimensions.

Consequently, this scenario assumes the user to be standing in a room-sized area without obstacles. The area should be large enough, so that the user can walk multiple steps without leaving it. Naturally, the VE must incorporate a mechanism to communicate the bounds of the area to the user, so that they do not accidentally leave it.

This scenario is the most demanding in terms of physical space. It is likely not feasible to provide this amount of space for every potential user of the system. This implies that it will probably have to be shared among multiple users and the hurdle for using it is significant. Hence, we see this scenario close to the border between everyday VR systems and laboratory setups. Incorporating Room-Sized SR might make this scenario more feasible for everyday use, as it might allow the system to be installed in rooms that are not exclusively used for it.

3 Use Cases

As stated above, when targeting an application for everyday use, it is vital to find the best suited usage scenario for designing efficient interaction concepts. In this section, we present use cases that we have previously explored in an immersive context. For each of them, we argue which usage scenario suits it best, to give an example of the reasoning to be employed when selecting a usage scenario. Additionally, we outline its impact on the interaction design.

3.1 Factory Planning

One application scenario for VR in the context of factory planning is allowing planners as well as prospective workers to get a life-sized impression of a factory before it has been finished. This can either be the case when a new factory is to be built or when changes to an existing factory need to be verified without disrupting its ongoing operation. In general, virtual walkthroughs enable users to identify design flaws, like insufficiently sized workspaces or incorrectly placed machines, in a cost- and time-effective fashion.

One such application is the factory layout planning tool *flapAssist* [2], which allows users to perform the aforementioned virtual walkthroughs (see Figure 2). It also provides them with a series of visualization techniques to gain access to further planning-relevant data, such as material flows. Furthermore, users are able to create annotations to persist planning results. The primary target platforms for *flapAssist* are CAVEs and HMDs. Clearly, HMDs are the better choice for everyday use given that access to CAVEs is usually very limited, due to their static nature and scarcity.

Figure 2: A user exploring a factory using the VR-based factory planning application *flapAssist* within a CAVE-like VE.

The usage environments in which *flapAssist* has to be used on a regular basis are best characterized by our standing and walking scenarios. For productive use, *flapAssist* is required to run in a planner's usual work environment, which resembles an office space, or on-site workshops with customers. Generally, standing can be thought of as the minimum requirement for the application, since one of the key benefits of VR here is its realistic, life-sized depiction of a factory's shopfloor. For a proper impression of the factory in relation to their bodies, users need to be standing—as they would in the real factory—and be able to perform minor motions, like kneeling down. While being able to walk around can further improve a user's impression, which maps to the walking scenario, this possibility can be forgone if space limitations prohibit it. In contrast, Sitting is usually not a feasible usage scenario, as it arguably affects the user's impression too much.

This choice of usage scenario has several implications on interaction design. For example, it is vital to implement a virtual travel technique that is usable while standing but does not require physical walking. Interaction elements like buttons, menus, etc., must always be reachable and not imply that one might walk towards them. Generally, as factories are usually large rooms that imply a lot of movement freedom, it is necessary to constantly remind the user that their physical space is more limited.

3.2 Graph Exploration

Graphs are ubiquitous data structures that describe relations between arbitrary entities. Graphs are usually visually inspected in their representation as a node-link diagram. This representation helps to explore, find, and understand complex relationships on various layers. An analyst inspecting a node-link diagram can benefit from its spread to 3D when accessed via semi- or fully-immersive display systems [9, 10]. This holds for graphs with a natural spatial embedding, e.g., brain region connectivity data and also abstract graphs given room in 3D. Additionally, the immersion generates the feeling of being present in the data, which further helps the analyst to build up a mental model of it. This mental model often is the key to understanding complex relationships.

This is one aspect of graph exploration. The second is the need to get out of the egocentric, "being part of the data" view and get an overview over more global relations. While this is possible in an immersive setting as well, the need to verify the collected insights with other data in spread sheets and functions plots often requires a switch to classic 2D visualizations or even other applications.

Thus, an immersive setting can only be successful, when it easily integrates into the existing workflows and workplaces of analysts and additionally allows a seamless transition between fully-immersive and native desktop content. As graphs are abstract objects, analysts generally do not require to use their own height as a reference for judging dimensions. Hence, the sitting scenario is best suited for graph exploration applications, as the standing and walking scenarios would not add any benefits. Instead, the sitting scenario provides the highest amount of comfort and makes transitions between immersive and conventional contexts as easy as possible.

For the interaction design, focusing on the sitting scenario primarily means that interactions need to be comfortable. All interaction elements have to be conveniently reachable from a sitting position. For example, requiring the user to touch a node of the node-link diagram forces them to precisely navigate to it, as it needs to be very close to be conveniently reachable. Naturally, this process would feel slow and tedious, compared to potential other approaches where nodes are selectable at a distance.

The user's physical environment is their desk, meaning that it could contain objects that are not related to the application. This means that the user not only needs to be aware of the limits of their physical space, but also of objects that they might collide with. On the other hand, objects in the user's surrounding, especially the desk's surface, could be incorporated into the interaction to provide convenient input metaphors with haptic feedback.

3.3 Automotive Design Reviews

Due to its competitiveness, the automotive industry requires continuous product improvement, and fast design cycles. In this context, VR is a valuable tool, as it enables designers to test many aspects of a new design without the need to build physical prototypes. The more realistic simulations are, the better designers can judge the functionality and aesthetics of a prototype. In addition, making VR technology more accessible for automotive designers enables them to validate or invalidate their ideas more often. This allows them to be more creative, as they can try out more experimental ideas without wasting many resources.

The designer needs to experience their product in the same way that a potential customer would. For example, they have to be able to walk around the prototype, bend down to look inside the trunk or duck to inspect the tires. Since most vehicles are small enough to fit inside one room, it is plausible that our walking scenario is best suited for automotive design reviews. Ideally, a designer would put on an HMD, enter a room that is equipped for VR design reviews and immediately inspect the newly designed vehicle.

For a quicker, less realistic inspection of the design, it might be possible to use the standing or sitting scenario, incorporating a form of virtual travel. However, we believe that the ability to use natural walking for navigation is critical when designing a system for VR design reviews of automobiles or other similarly sized objects.

Designing for the walking scenario, due to the short distance navigated, no navigation technique is needed in most cases, other than natural walking. Since the focus of this scenario is realism, all interactions should be performed as naturally as possible. For example, when the user wants to look beneath the vehicle, it is preferable to raise the vehicle using the metaphor of a lifting ramp, rather than flying the user underneath it. Since the user can be assumed to focus on the vehicle and remain in its close proximity, the user does not need to be constantly reminded of the bounds of the physical space. Instead, the bounds should only be brought to attention when the user is about to leave them.

4 Conclusion

We proposed the three usage scenarios sitting, standing, and walking for VR applications to be used in an everyday context. They are based on the amount of the user's mobility. For each scenario, we have discussed the challenges, as well as the opportunities that arise from it. It is our position that the first step in designing a VR applications for everyday use should be the selection of an appropriate usage scenario. For the three usage scenarios presented in this paper, we proposed design guidelines. To illustrate our position, we presented everyday applications and for each of them indicated the usage scenarios that are best suited for them. For each application, we also illustrated the impact that their usage has on interaction design.

With this work, we aim at raising awareness of the necessity to design for a particular usage scenario, to ensure usability in an everyday context. While other scenarios are conceivable, like a scenario, where the user is sitting in a turning chair, so they can rotate while being seated, the three scenarios will hopefully provide a solid starting point.

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