Extending HMD-based Virtual Reality through Wind and Warmth

Mario Heinz[1], Henrik Mucha[1], Carsten Röcker[1,2]

Institute Industrial IT (inIT), OWL University of Applied Sciences, 32657 Lemgo, Germany[1]
Fraunhofer IOSB-INA, 32657 Lemgo, Germany[2]

{mario.heinz, henrik.mucha, carsten.roecker}@hs-owl.de

Abstract

In recent years, the technologies in the field of virtual reality have evolved considerably. Especially as a result of the further development in the field of head mounted displays, there is an increasingly broad field of application for activities in the professional and private life. Besides the optimization of the visual representation, developers are currently focusing on the integration of multimodal interaction methods and feedback strategies in order to make virtual environments increasingly more realistic. While existing systems are already able to provide users with multimodal sensations via different sensory channels, the integration of systems for the presentation of environmental influences generally remains only slightly considered. Therefore, in this paper, we will address several aspects regarding the provision of wind and warmth in HMD-based virtual scenarios and introduce our implementation of a prototypical system which we want to discuss with the community.

1 Introduction

Over the past years, technologies in the field of virtual reality (VR) have become increasingly evolving and todays VR devices are applicable for different scenarios in the context of gaming, professional training, data visualization, design, architecture, marketing and other fields of activity (Sherman & Craig, 2002; Burdea & Coiffet, 2003; Dörner, 2014). The presentation of immersive virtual realities is mainly achieved by using two different technologies: the currently very popular head-mounted displays (HMDs) and Cave Automatic Virtual Environments (CAVEs) which can primarily be found in scientific laboratories (Sherman & Craig, 2002). While HMD-based systems are build up on head-worn devices with integrated displays and special lenses, CAVEs are based on multiple wall projections to visualize a virtual environment (Cruz-Neira et al., 1993; DeFanti et al., 2009). Furthermore, both technologies utilize a multitude of interaction and navigation methods allowing both virtual and real movements in virtual environments (Dörner, 2014). Since the beginning of the development of virtual reality systems, developers have pursued the goal of making virtual worlds as realistic as possible. In this context, a multitude of systems for the presentation of information on different sensory channels has been developed and evaluated (Burdea & Coiffet, 2003; Dörner, 2014). While most of the current VR systems are already able to provide users with visual, auditory and haptic-tactile feedback while interacting with virtual objects, the presentation of

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environmental influences has so far been addressed only very slightly (Sherman & Craig, 2002, Dörner, 2014).

Therefore, in this paper we will present a prototypical system to provide wind and warmth in virtual reality scenarios in order to elaborate the integration of environmental influences. In section two, we take a look at the current state of research towards the presentation of environmental influences in virtual reality. In section three, we will introduce the relevant hardware and software aspects of our system. In section four, we will describe our findings during a first technical evaluation and the practical use of our system during a workshop with students. In section five and six we will discuss our findings regarding the technical and practical aspects of our system and give an outlook on future improvements.

2 Related Work

Most of the current VR systems can already provide users with visual, acoustic and haptic-tactile stimuli in order to increase the realism of virtual scenarios. The presentation of environmental influences such as thermal stimuli or the sensation of wind on the other hand has been addressed only slightly. In this context, (Dinh et al., 1999) evaluated the importance of multimodal sensory input for the memory and the sense of presence regarding virtual environments. Their results indicate that multimodal stimuli contribute to the improvement of the experience of a virtual environment. (Jones & Ho, 2008) and (Jones, 2016) discussed central aspects in the scope of the evolution and application of so-called thermal displays, which allow to provide users with thermal stimuli such as heat or cold. The key problem regarding the application of thermal displays in virtual reality systems concerns the integration of these devices in VR scenarios. (Moon & Kim, 2004) introduced a system to provide users of a VR system with the sensation of wind through multiple fans mounted on a cage located around the user. (Hülsmann et al., 2013; Hülsmann et al., 2014) presented a similar system to provide users with sensations of warmth and wind by integrating fans and heat lamps into a CAVE. But, because of the restricted area, both systems only allow a limited amount of real movement. However, this is in contradiction to the improvement of the realism of virtual realities. Furthermore, (Benali-Khoudjal et al., 2003) introduced a thermal feedback model for virtual reality. Some developers are also working on wearable solutions like the *Teslasuit* mentioned by (Revell, 2018) which consists of electrical stimulators and other actuators to generate sensations of wind, warmth or cold. But these solutions are generally limited due to the fitting of the suits for certain body proportions. (Knierim et al., 2017) introduced another interesting solution based on small flying drones to provide users with tactile information about existing objects within the environment which could also be used to provide users with different environmental influences.

Compared to the existing solutions, our system follows a more modular and flexible approach to enable an application for different environments and activities. This is achieved by implementing controllers to trigger the power connection of commercial devices such as fans or heat lamps.

3 Prototype

In this section, we will introduce the technical aspects of our prototypical implementation of a system to provide wind and warmth in HMD-based VR scenarios by describing the implementation and linking of the hardware and software. Figure 1 shows a general overview of the prototypical system and its components.

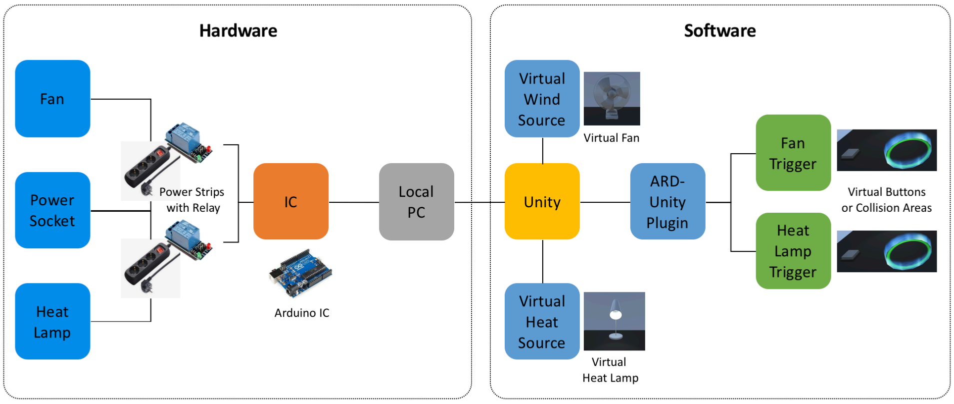

Figure 1: Overview on the hardware and software parts of the prototypical system.

3.1 Hardware

For the visualization and the provision of acoustic and basic haptic-tactile sensations within the virtual environment, we used an *Oculus Rift* VR HMD and the associated controllers connected to a local PC. For the provision of wind and warmth, we used a commercial fan and heat lamp with ordinary power connector cables. Each device was connected to a power strip extended with a relay to control the power connection via an *Arduino* microcontroller (Figure 1) which was also connected to the local PC via an USB cable. In this way, the system is able to control any device which can be activated by its power connection.

3.2 Software

The system was implemented using the Unity game development platform. Because the current system was intended to be a first prototypical solution, we used multiple existing software libraries and plugins, such as the *VRTK – Virtual Reality Toolkit*[1], the *Oculus Unity SDK* and the *ARDUnity Basic Plugin*[2] to reduce the implementation effort. The *Oculus Unity SDK* was thereby used to integrate the headset and the controllers into the Unity environment. The *VRTK – Virtual Reality Toolkit* provides a wide range of interaction methods for different VR devices.

[1] https://vrtoolkit.readme.io

[2] https://assetstore.unity.com/packages/tools/input-management/ardunity-basic-60643

For the control of the power strips we used the *ARDUnity Basic Plugin* which allows to communicate with Arduino microcontrollers within Unity to change the electric status of output pins or read data from attached sensory devices. Therefore, the plugin generates a sketch to be uploaded to the microcontroller in order to establish the connection with objects and scripts in Unity. Additionally, the plugin offers a so-called *Wire Editor* to graphically wire different objects and scripts to create various sequences. Figure 2 shows the wiring used in our current setup to connect the fan and the heat lamp via the plugin and the serial port to our scene.

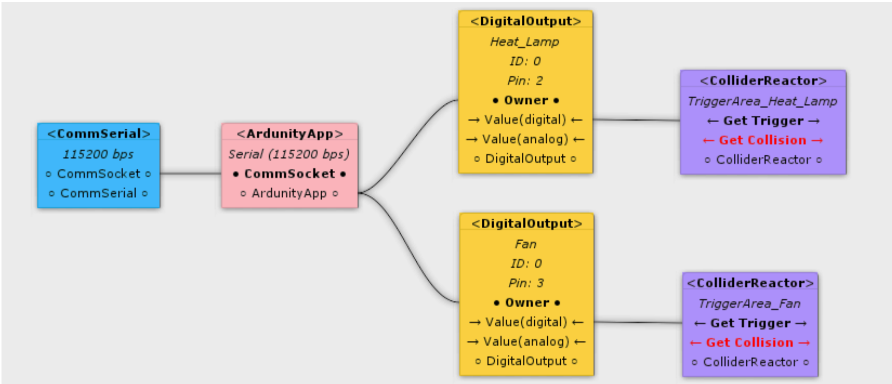

Figure 2: Wiring of the different objects in the ARDUnity plugin.

4 First Evaluation

During a first technical self-evaluation, we wanted to examine if the sensation of wind or heat would be reduced due to the wearing of the HMD. Further, we wanted to know if the sensation of wind and heat provided through a fan and a heat lamp enhances the experience of a virtual scenario. Therefore, we build up a simple virtual scene consisting of a square floor, a table with two switches and two activation areas, a fan and a heat lamp (Figure 3). In the real world, we used masking tape to define a starting point on the floor of our lab. In the virtual scene, the starting position of the user was located approximately one meter away from the table. The user then had to walk over to the table with the switches and the two activation areas placed on it. Each of the switches and the activation areas was connected to either the fan or the heat lamp object. The switches were activated by touching the cube with one of the controllers and deactivated via a second touch. The activation areas, on the other hand, were activated by holding one of the controllers in the area above the circles and deactivated by leaving the area. On activation, the fan was animated by a rotation of the blades while the activation status of the lamp was visualized by a triggered pointing light.

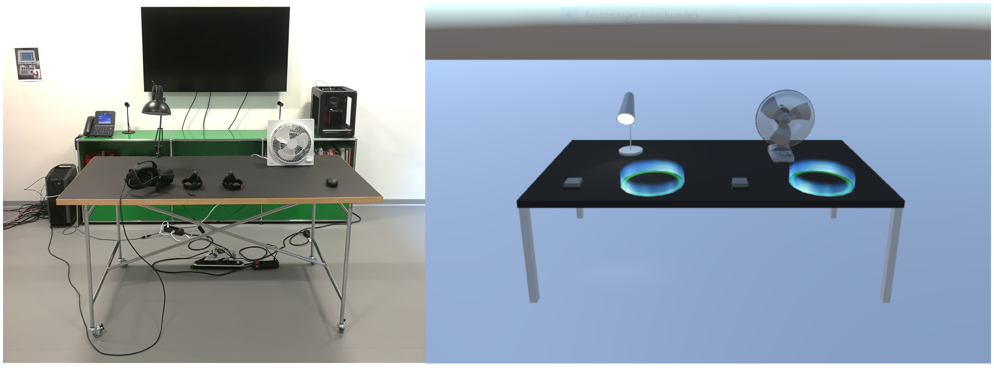

Figure 3: Preview of the real and the virtual scene for the first technical evaluation.

During the evaluation, the user was positioned at the defined starting position in front of the masked area on the floor, wearing the HMD and holding a controller in each hand. After launching the scene, the user was asked to step forward to the table and to freely try out the two different activation methods for the fan and the heat lamp. To compare the effect of the physical actuators, the activation of the real devices was deactivated for the first couple of minutes and then activated via the Unity platform. We also limited the scenario to pure real movements since mixed movements could create offsets between the virtual and real position of the devices.

After experiencing the scene, the individual impressions regarding the environmental influences were discussed. The general conclusion was, that the wind and warmth generated by the fan and the heat lamp was a good enhancement for the virtual scene. In addition, the limitation of the sensation in the area of the face was subjectively rated as noticeable but not too critical.

Additionally, the provision of wind was tested during a one-week workshop called *Forensic Spaces*[3] in the context of the event *Detmolder Spaces*, where small groups of students had to create their own interactive virtual environment. The goal of the workshop was to implement a scenario where the user had to solve a criminal case or to escape a virtual room by following different hints and completing various tasks. Regarding our system, this workshop was an ideal way to examine its practical application in complex virtual environments on an early stage. The system was presented to the twelve participants as an optional element to enhance the realism of their virtual environments. In this context, the fan was used in one scenario to enhance the impression of a wind breeze through a window opened during the story. For the use in other scenarios, however, we registered a key limitation in the applicability of our system based on the way the user had to navigate through the scene as mentioned above. In the first case the user had to walk across the scene and the fan was placed on the specific location where the window was located in the virtual world. The other scenarios, on the other hand, used a navigation method via teleportation where the user had to point to a position in the scene to be automatically transported to this location. In this setting, the position of the fan only remained

[3] https://www.m-i-a-d.de/2018/04/08/forsensic-spaces-workshop-at-detmolder-raeume-23-04-18-27-04-18/

valid as long as the user did not change the position in the real world. Otherwise, the position of the fan relative to the user was shifted which had a negative impact on the overall user experience.

The conversation with the participants of the workshop after their first experience with the system provided similar results as in the initial technical evaluation. The applicability of the system was rated as a good solution to enhance virtual scenarios. Furthermore, the limitation of the sensation by wearing the HMD was also considered as not too critical. Additionally, several potential extensions for the systems where discussed, such as a vibrating ground plate to provide sensations comparable to a lift or a moving platform.

5 Conclusion

In this paper, we presented a prototypical system to provide wind and warmth in virtual environments to enhance the realism in virtual reality scenarios. Further we discussed some key limitations regarding the provision of environmental influences based on our choice of hardware and our interaction and navigation concept. The first technical evaluation and the practical application within the workshop generally provided a positive feedback and important information regarding the limitations of the current system, taking into account its prototypical character. Both the air flow generated by the fan and the heat generated by the heat lamp were subjectively rated as a good support for experiencing the virtual scene. Regarding the applicability, the system generally revealed good potential to enhance the realism of virtual environments and the sensation of wind and warmth felt quite natural while wearing the headset.

In case of the navigation method, both pure real and virtual movements are covered by our system. Mixed navigation methods, on the other hand, could lead to an offset between the real and the virtual position of an actuator, as described in section 4. A possible solution for this problem would be to attach the actuators directly to the user's body, but this would significantly increase the complexity of the system. For pure virtual navigation scenarios, it would also be possible to build a system like presented by (Hülsmann et al., 2014) based on our implementation. The use of a microcontroller-based solution offers a high flexibility regarding the integration of additional actuators and sensors for various activities. Furthermore, since the Unity platform is becoming a central development tool for both virtual and augmented reality scenarios, our system could also be used for augmented reality approaches. This opens up a wide range of applications like user research, professional training, education or smart home.

6 Future Work

In the future, we plan to extend and improve the prototypical system by adding new actuators and sensors in order to provide the user with additional and enhanced environmental sensations. To reduce the amount of cabling in the surrounding of the user and to allow to place modules on the user's body, we further plan to replace the currently used microcontrollers with

Wi-Fi-ready devices which can be addressed over a local Wi-Fi network. We will also iteratively evaluate our system by performing user studies and questionnaires in order to collect information for future improvements.

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Authors

Heinz, Mario

Mario is currently working as a research assistant at the HCI Lab at Ostwestfalen-Lippe University of Applied sciences in Lemgo, Germany. He holds a bachelor degree in computer science and a master degree in cognitive and movement science from Bielefeld University. His research is focused on the development and evaluation of augmented-reality based interaction devices and feedback technologies for assistive systems in industrial contexts.

Mucha, Henrik

Henrik currently works as a research assistant at the Institute Industrial IT (inIT) in Lemgo, Germany where he is part of the HCI Lab. Henrik holds degrees in Industrial Design (Dipl.-Des., University Duisburg Essen) and Usability Engineering (M.Sc., Rhine-Waal University of Applied Sciences). As a Usability Engineer, Henrik focuses on the methods of the human-centred design process and their application in workshops. His current work is concerned with human-computer interaction in industrial contexts.

Röcker, Carsten

Carsten Röcker is head of the research group on Intelligent Assistance System at the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation (IOSB), director of the Institute Industrial IT, and professor for User Experience and Interaction Design at the OWL University of Applied Sciences. His current research interests revolve around intelligent assistance systems, human-computer interaction and technology acceptance.