Nomadic Virtual Reality: Exploring New Interaction Concepts for Mobile Virtual Reality Head-Mounted Displays

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ABSTRACT

Technical progress and miniaturization enables virtual reality (VR) head-mounted displays (HMDs) now to be solely operated using a smartphone as a display, processing unit and sensor unit. These mobile VR HMDs (e.g. Samsung GearVR) allow for a whole new interaction scenario, where users can bring their HMD with them wherever they want and immerse themselves anytime at any place (nomadic VR). However, most of the early research on interaction with VR HMDs focused around stationary setups. My research revolves around enabling new forms of interaction for these nomadic VR scenarios. In my research I choose a user-centered design approach where I build research prototypes to solve potential problems of nomadic VR and evaluate those prototypes in user studies. I am going to present three prototypes revolving around current challenges of nomadic VR (input and feedback).

Author Keywords

nomadic VR; mobile VR; VR interaction; Virtual Reality;

ACM Classification Keywords

H.5.2. [Information Interfaces and Presentation] : User Interfaces: Input Devices and Strategies, Interaction Styles

INTRODUCTION

After the first big wave of virtual reality (VR) in the 90s, VR head-mounted displays (HMDs) are once again at a state where they can potentially penetrate the consumer market. Major companies such as Facebook, Samsung and HTC are releasing consumer products (e.g. GearVR) this year (2016). Mobile VR has the potential to make virtual reality as ubiquitous as smartphones. Due to the low price of these mobile VR HMDs, they are more likely to penetrate the consumer market. Therefore, enhancing the usability and interaction of these mobile devices could potentially help them with user acceptance.

Research around VR interaction mostly focused on stationary concepts where you assume you have control over the environment [24]. However, the nomadic VR scenario comes with new research challenges such as "how to design input techniques in a public space". I decided to choose an engineering approach by extending the interaction space of mobile VR HMDs through additional hardware such as sensors and actuators to fit the specific scenario. Similar to the evolution of the smartphone which after its first release changed drastically over time in terms of sensing and actuation (e.g. camera, gyro, touch input, vibration motor). I expect the same to happen with mobile VR HMDs which will extend their input and output capabilities after a significant benefit for the user can be shown (e.g. eye-tracking to enable foveated rendering).

The research goal of my thesis is to identify the specific interaction challenges in nomadic VR and address those by proposing possible solutions through research prototypes. These are being evaluated in user-studies comparing them to the state-of-the-art in terms of immersion, engagement, enjoyment and simulator sickness. The focus of my thesis lies on interaction and end-users/consumers using VR for leisure, rather then on professional applications.

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NOMADIC VIRTUAL REALITY

Nomadic VR can be seen as an interaction scenario where a user operates a mobile VR HMD in an uninstrumented environment often in social settings (e.g. commute to work in a subway). In contrary to Kleinrock et al. [8] my focus for nomadic virtual reality lies on interaction scenarios/concepts and not the underlying technology infrastructure. The technology used for nomadic VR is a mobile VR HMD but the interaction scenario is not fully mobile (e.g. no walking condition). To interact with a mobile VR HMD a user will pick a spot where he or she feels comfortable to interact and immerse him or herself.

Research questions for nomadic VR can partially be derived and adapted from research questions of stationary VR [24, 11]. Nomadic VR comes with additional constraints for some of the research questions such as input. As an example, the HTC Vive controllers can currently be considered as one of the better ways to interact with stationary VR systems but would force an additional accessory upon the user in the nomadic VR scenario. The Leap Motion sensor can be integrated into a mobile VR HMD and allows for hand tracking in nomadic environments but would force the user to spread their arms away from the body and potentially bump into and touch things and people in the surrounding. These examples show that a stationary solution does not necessary apply to the nomadic VR scenario. Nomadic VR also comes with additional challenges such as social acceptance. The following list of research questions is partially derived from the prior work. In my thesis I am currently planning a bigger survey to derive further research questions and challenges of nomadic VR HMDs and extend/modify the following list.

- RQ1 Input: Which input concept allow for an efficient interaction for the nomadic VR scenario ?

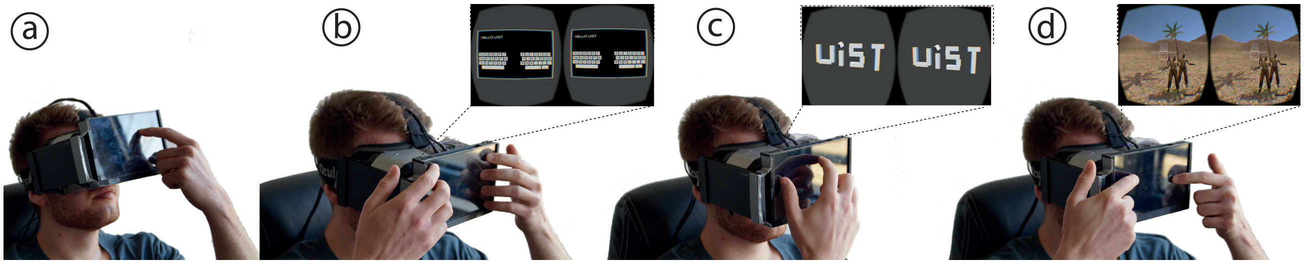

Figure 1. (a) A user interacting with FaceTouch, a multi-touch surface mounted on the back of a VR HMD. FaceTouch allows for precise interactions which can be used to implement applications such as text entry (b) or 3D modeling (c). Leveraging the sense of proprioception a user is able to blindly interact with control elements such as used in a gamepad to control a shooter game (d).

- RQ2 Feedback: How to enable additional sensory feedback for mobile VR HMDs which increase the level of immersion ?
- RQ3 Social Acceptance: How to increase the social acceptance of mobile VR HMDs when used in public places ?

One of the big constraints for nomadic VR is to avoid additional accessory for the user. All of the solutions should be in one way either integrable into the HMD itself or into other devices of the user (e.g. smartwatch). In the future, mobile VR HMDs itself can be integrated inside of a bumper case for the smartphone or even become part of the future smartphone itself. The reason for this ”accessory constraint” is that most mobile appliances are fighting for the ”pocket space” of the user. A device with only one specific feature is more likely to not be brought along compared to a general device such as the smartphone [7]. Imagine you would have to bring an additional mp3 player, a camera and a video player with you on your daily commute. For VR to become an integral part of users everyday life it has to become an integral part of every smartphone. One can imagine a future, where after receiving a picture from a friend who is currently on vacation, instead of only looking at it on your smartphone screen you would just hold your smartphone to your face and immerse yourself into a 360 scene being able to actually look around, interact and feel the environment.

DISSERTATION STATUS

In my thesis I currently focused on the first two research questions (RQ1 and RQ2). In the following I am going to present three research projects which addressed these questions.

FaceTouch [Conditionally Accepted at UIST 2016]

With FaceTouch [4] our goal was to design an interaction concepts for the nomadic VR scenario which extends the input capabilities of mobile VR HMDs (RQ1). We focused on short interaction bursts (utilitarian interaction to select content or input text) which fit the nomadic VR scenario.

FaceTouch is a novel interaction concept for mobile VR HMDs that leverages the backside as a touch-sensitive surface (figure 1. With FaceTouch, the user can point at and select virtual content inside their field-of-view by touching the corresponding location at the backside of the HMD utilizing their sense of proprioception. This enables a rich interaction (e.g. gestures) in nomadic scenarios without having to carry additional accessories (e.g. a gamepad). To evaluate the performance of FaceTouch we conducted two user studies. In the first study we measured the precision of FaceTouch in a display-fixed target selection task using three different selection techniques showing a low error rate of 2% indicating the viability for everyday usage. The second user study compared three different mounting positions (face, hand and side) showing that mounting the touchpad at the back of the HMD resulted in a significantly lower error rate, lower selection time and higher usability. Finally, we present interaction techniques and three example applications that explore the FaceTouch design space.

Overall, we showed how by simply changing size and location of the currently widely spread touchpad at the temple, mobile VR HMDs can increase the interaction capabilities and enable features such as text entry.

GyroVR [Conditionally Accepted at UIST 2016]

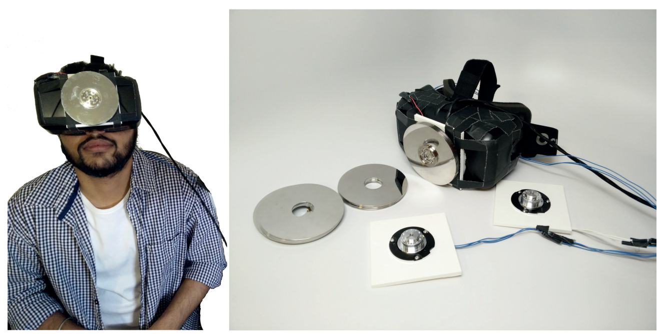

Figure 2. Left: A user wearing a VR HMD with GyroVR attached. Right: A prototype implementation of GyroVR attaching flywheels on the front of an Oculus Rift DK2.

The work around GyroVR [5] aimed to enable new forms of haptic feedback for mobile VR HMDs (RQ2) which work in a nomadic VR scenario.

GyroVR uses head worn flywheels designed to render inertia in nomadic VR (figure 2). Motions such as flying, diving or floating in outer space generate kinesthetic forces onto our body which impede movement and are currently not represented in VR. We simulate those kinesthetic forces by attaching flywheels to the users head which leverage the gyroscopic effect of resistance when changing the spinning axis of rotation. GyroVR is an ungrounded, wireless and self contained device allowing the user to freely move inside the virtual environment. We build several iterations of the prototype exploring the optimal mounting position on the users body. In a final evaluation we measured the impact of GyroVR on immersion, enjoyment and simulator sickness in different mounting positions on the head (back and front). The results showed that participants preferred the front mounting which resulted in the highest level of immersion and enjoyment. We additionally raised the question of how realistic haptic forces have to be which are generated for VR.

Our preliminary results indicate that the level of immersion can also be increased by using unrealistic forces (as we had in one of our example applications) as long as they fit the certain environment. Further research must be conducted to show what exactly must be fulfilled that users accept these unrealistic forces. Overall, GyroVR showed how it is possible to create haptic feedback in nomadic VR scenarios by modifying a mobileVR HMD with flywheels.

SwiVRChair [CHI 2016]

Figure 3. Left: A participant being rotated inside a virtual scene sitting on the SwiVRChair. Right: The physical prototype of the SwiVRChair

With SwiVRChair [6], we again focused on adding additional sensory feedback for mobile VR HMDs in nomadic VR scenarios (RQ2). In contrast to GyroVR we picked a different approach by not modifying the HMD itself but a swivel chair which is used to initiate the nomadic VR experience. We picked a swivel chair since its a perfect tool to explore 360 degree content which is a promising application scenario for VR.

SwiVRChair is a motorized swivel chair to nudge users orientation in 360 degree storytelling scenarios (figure 3). Rotating a scene in VR without actual physical movement can lead to simulator sickness. This reduces the freedom of storytellers since they have no way of nudging users attention. SwiVRChair allows creators of 360 degree VR content to be able to rotate or block users movement to either show certain content or prevent users from seeing something. We implemented SwiVRChair by modifying a regular swivel chair using a 24V DC motor and an electromagnetic clutch. The clutch was an essential part in the design since it allows the user to always break out of the computer initiated rotation. We evaluate the concept by developing two demo scenarios of a 360 degree movie and conducting a first user evaluation (n=16). The focus hereby was on presence, enjoyment and simulator sickness of SwiVRChair in comparison to a regular swivel chair.

Our results show that users enjoyed the experience using SwiVRChair and rated the immersion and enjoyment to be significantly higher compared to a regular swivle chair. We further observed the effect that participants valued the aspect of ”leaning back” and not having the pressure of searching inside the scene for the next narrative. Overall, our work shows how a currently regular piece of furniture can be extended in the future to enhance 360 degree story telling applications for mobileVR HMDs.

RELATED WORK

I will mainly focus on HCI research for VR HMDs and divide the prior art in *Input* and *Feedback*. CAVE environments were predominant in the last years of VR research but only partially influence my thesis.

Input: Concepts for interaction in VR are mostly based on the field of 3D interaction techniques [1]. Those can be classified as exocentric (third-person view) and egocentric (first-person view) interaction metaphors [16]. My current projects mostly focused around egocentric interaction concepts of which the most prevalent are the virtual hand and virtual pointer metaphors [1, 17]. Virtual hand metaphors work by tracking the users hands to allow for interact with content within arms reach [10] (e.g. Leap Motion). This approach partially breaks with the nomadic VR scenario since it forces the user to reach into an unknown environment, potentially bumping into and touch people or objects in the surrounding. Virtual pointer metaphors rely on casting a ray into the virtual scene to enable user interaction [12]. Several techniques were proposed to determine the rays orientation which mostly rely on tracking the users hand [13, 15]. More recent research on mobile VR already started to use the additional sensors of the smartphones such as magnetometer or gyroscope to allow for novel interaction concepts [20, 22].

Feedback: One of the big directions of research in VR is focused around generating haptic feedback [9, 18] which can be divided into kinesthetic and tactile feedback. Motion platforms which often induce kinesthetic feedback are mostly based on the Steward platform [21]. Early prototypes in CAVE systems attached exoskeletons [23] or pulley system [14] to the users limbs. Most of these feedback mechanisms work only with specialized hardware or environments dedicated for this one task. More recent projects such as HapticTurk [2] and TurkDeck [3] used the approach of harvesting people in the surrounding to generate haptic feedback. Furthermore, some research projects on feedback in VR which were not particularly tailored towards nomadic VR presented concepts which still would fit the nomadic VR scenario [9, 19].

My goals is to publish my work in HCI venues such as CHI and UIST and focus on the interaction challenges for mobile VR HMDs.

RESEARCH SITUATION

I am currently in the third year of my PhD at the Institute of Media Informatics at Ulm University, Germany. The program I am enrolled in does not have any time constraints but I plan to hand in my thesis in approximately two years. From the Doctoral Consortium I hope get valuable feedback on my research direction and approach since at the current state I am still able to adjust those.

FUTURE WORK

Until now all the projects I have done for nomadic VR were focusing on more traditional VR interaction research questions (input and output). I am currently planing to collect data with early adopters of mobile VR HMDs to be able to identify more specific challenges for the nomadic VR scenario. Furthermore, I am working on RQ3 (social acceptance) which is something most technologies face which have to be operated in a public setting. One of my hypotheses is that mobile VR HMDs will have similar problems as Google Glass had, since bystanders are not able to see and understand what the immersed user is doing.

The overreaching goal of my thesis will be to identify specific problems inside the nomadic VR scenario and solve some of them through future prototypes which are evaluated in user studies. The findings of my thesis will extend the prior work of interaction research for virtual reality in the specific context of nomadic VR. Additionally, I hope that my work will also have an impact onto the VR industry and help to support the user acceptance of future mobile VR HMDs since some of my presented prototypes can already be implemented using currently available off the shelf hardware (e.g. FaceTouch).

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