SwiVRChair: A Motorized Swivel Chair to Nudge Users' Orientation for 360 Degree Storytelling in Virtual Reality

Jan Gugenheimer, Dennis Wolf, Gabriel Haas, Sebastian Krebs, Enrico Rukzio
Institute of Media Informatics, Ulm University, Ulm, Germany
<firstname>.<lastname>@uni-ulm.de

Figure 1. Left: A participant being rotated inside a virtual scene sitting on the *SwiVRChair*. Right: The physical prototype of the *SwiVRChair*

ABSTRACT
We present *SwiVRChair*, a motorized swivel chair to nudge users' orientation in 360 degree storytelling scenarios. Since rotating a scene in virtual reality (VR) leads to simulator sickness, storytellers currently have no way of controlling users' attention. *SwiVRChair* allows creators of 360 degree VR movie content to be able to *rotate* or *block* users' movement to either show certain content or prevent users from seeing something. To enable this functionality, we modified a regular swivel chair using a 24V DC motor and an electromagnetic clutch. We developed two demo scenarios using both mechanisms (*rotate* and *block*) for the Samsung GearVR and conducted a user study (n=16) evaluating the presence, enjoyment and simulator sickness for participants using *SwiVRChair* compared to self control (*Foot Control*). Users rated the experience using *SwiVRChair* to be significantly more immersive and enjoyable whilst having a decrease in simulator sickness.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

Author Keywords
SwiVRChair; Virtual Reality; Consumer Virtual Reality; Virtual Environments; 360 Degree Video; 360 Degree Storytelling

INTRODUCTION
Whilst VR Head-Mounted Displays (HMDs) have been researched for a long time in labs, we argue that upcoming research will have to focus on actual domestic/consumer use of HMDs and therefore address new upcoming problems and opportunities. Since Oculus announced the formation of the Oculus Story Studio[1], a team focusing solely on creating virtual reality movies, the field of 360 degree story telling has received more public attention and can become one big selling point of consumer virtual reality (VR).

Since 360 degree movies are a fairly new medium, creators are facing several challenges such as controlling the attention of a user. In traditional movies this is done by applying cuts and tracking shots which is not possible or advisable in VR since rotating the virtual scene in front of the user's eyes will lead to simulator sickness [11]. One of the reasons this effect occurs is when the physical movement (measured by the vestibular system) and the visual movement are not coherent.

Since most current VR content is advisable to be consumed using a swivel chair [3], we propose the concept of physically moving the user by rotating the chair with an attached motor (figure 1). We implemented *SwiVRChair* by adding a 24V motor and an electromagnetic clutch connected through a timing belt (figure 3). The magnetic clutch allows the user to still resist and break free of the controls of *SwiVRChair* without harming the motor. Therefore, we do not try to fully control the user's view but consider it more as a nudging and an immersing of the user into the scene.

In a user study (n=16) we evaluated the effect of *SwiVRChair* compared to *Foot Control* in terms of presence, enjoyment and simulator sickness. Participants watched two 360 degree scenes we designed using Unity3D containing both mechanics (*rotate* and *block*) resulting in a significantly higher rating for *SwiVRChair* in terms of presence and enjoyment while having a decrease in terms of simulator sickness compared to *Foot Control*. We offer the source code and building instructions as an open source platform.[2]

CONCEPT AND DESIGN SPACE
OculusVR founded Oculus Story Studio which is a company of former Pixar employees who focus on creating movies in VR which immerse the users in the story and are happening in 360 degree around them (figure 1). The goal of *SwiVRChair* is to offer a low-cost motion platform which can be used in current households and enhance the experience for VR content such as 360 degree movies. *SwiVRChair* uses a common swivel chair which is already

[1]https://storystudio.oculus.com/en-us/

[2]http://www.uni-ulm.de/?swivrchair

CHI'16, May 07-12, 2016, San Jose, CA, USA

DOI: http://dx.doi.org/10.1145/2858036.2858040

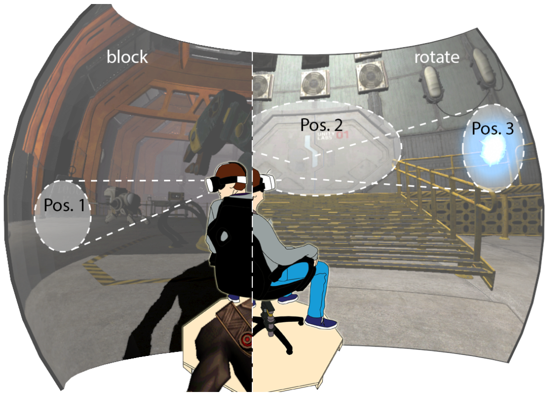

Figure 2. On the left, the concept of *block*: The user is turned away from the monster (Pos. 1) and only sees its shadow in front of them. The user can either accept this or fight the blockage using his feet to turn the chair. On the right, the concept of *rotate*: The user is guided through the scene and certain content such as the purpose of the door (Pos. 2) is explained in more detail. In case the user gets bored, they can start turning away from the current content.

wide spread in households and enhances it by adding a motor and a clutch (figure 3) to be able to automatically rotate the chair.

This offers a design space based around rotational movements to control the user's orientation inside a virtual 360 degree scene. We emphasize in our concept two basic actions *rotate* and *block* which we offer as a tool for content creators to use inside a 360 degree immersive virtual environment (IVE).

rotate. In the basic scenario the user is rotated towards certain content inside the IVE (figure 2). This allows the content creator of 360 degree IVE to simulate aspects of movies such as cuts or tracking shots. Similar to traditional movies these can be used to introduce the scene or have a more artistic aspect. The rotation can also be used to immerse the user more into the scene (e.g. as the result of an explosion the users will twist around). The rotation can be controlled by the parameters speed (how fast will the user rotate) and target (what angle should the user face at the end of the rotation).

block. The concept of blocking allows for the orientation of *SwiVRChair* to be kept at a certain angle (figure 2). This can be used to hide certain information from the user (e.g. a monster approaching from behind). This is a novel technique to story telling which derives from the freedom of looking around inside a 360 degree scene which was not possible in traditional cinema. Similar to *rotate*, *block* can either be used as a cinematic technique or to immerse the user even more into the IVE (e.g. some virtual character is holding the user).

Little is known about 360 degree storytelling, therefore we refer to the currently only available insights, "5 Lessons Learned While Making Lost" which were released by Oculus Story Studio [1]. One of the lessons was "Let go of forcing the viewer to look somewhere" which firstly sounds contrary to the *SwiVRChair* concept but is something that we built as an essential part into the concept of *SwiVRChair*. Both concepts of *SwiVRChair* (*block* and *rotate*) always allow the user to break out of the chair's movement. Therefore we see both concepts just as a nudging, which the user can either accept and enjoy or can choose to break out of and explore the whole environment by themselves. This was one of the reasons why we decided to use a magnetic clutch (more details in the implementation section) and did not use a footrest. We wanted the user to still feel (and be) in control throughout the whole experience.

IMPLEMENTATION

SwiVRChair is powered by a type G42x40 24V DC Dunkermotor having a torque of 5.7 Ncm and 3100 rpm. In addition we use a planetary gearbox (PLG G42 S) consisting of metal gear rings having a 32:1 gear reduction. In a prior version we used a gearbox (PLG 42 K) made out of plastic rings which broke due to the force which was applied by fast rotation and direction changes. We added a further gear reduction using a toothed belt with a ratio of 3:1 resulting in an overall torque of ≈5.5 Nm and ≈33 rpm (without any load). This is enough to theoretically create a full rotation of an ≈100kg person 30 times a minute. However, the angular acceleration starting from a non-moving chair is more relevant, since it is unlikely that a participant will be rotated more than twice around its own axis. Using our setup (running on 20V) we are able to rotate an up to 100kg heavy participant from a standing position in 2.3 seconds half a revolution.

The magnetic clutch (Kendrion) consists of two parts, one attached to the drive shaft on the gearbox and the other attached to the toothed belt wheel. These two parts are not connected mechanically. The electromagnetic field created by applying 24V locks the two parts and the rotation of the motor is transfered through the toothed belt to the chair shaft. Once a user blocks the rotation using their feet the force generated exceeds the maximum capacity of the clutch and the electromagnetic field breaks. This principle allows the user always to break free of the movement of *SwiVRChair* without harming the gearbox and without having to apply too much force. To measure the precise orientation of the chair we attached a magnetic rotary positions sensor by arms (AS5047D) at the bottom of the chair shaft.

Figure 3 shows the implementation of *SwiVRChair*. We removed the rollers from a standard office swivel chair to block movement during a rotation and placed the chair on a wooden platform to position all the cables underneath. The motor and clutch were placed inside a metal frame and attached to the chair shaft. Both the motor and the clutch are controlled using a motor shield (figure4) connected to an Arduino Mega 2560. The motor shield is connected to a 24V power supply and transfers an incoming PWM signal from the Arduino to a Voltage (0 - 24 V). The Arduino communicates via a bluetooth shield (BLE Shield) with the Samsung GearVR headset running a Unity3D application of the IVE. This allows us to control the rotation of the chair from within the Unity scene.

The rotation algorithm of *SwiVRChair* is modeled using a *"critical-damped-spring"* system. This simulates a spring between the start and the target point having a certain stiffness (determined empirically) whereby the *"ciritical-damping"* ensures that the spring returns to equilibrium as quickly as possible without oscillating. Using this model allowed to compensate for friction and rubbing which a user generates with their feet and resulted in an overall smooth rotation.

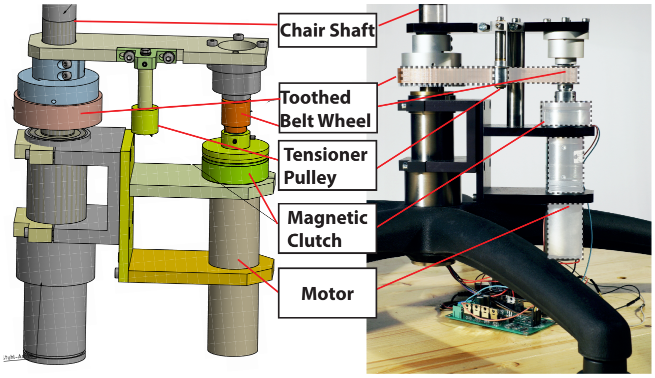

Figure 3. On the left, the 3D model of the chair construction and on the right the actual implementation showing the attachment to the chair

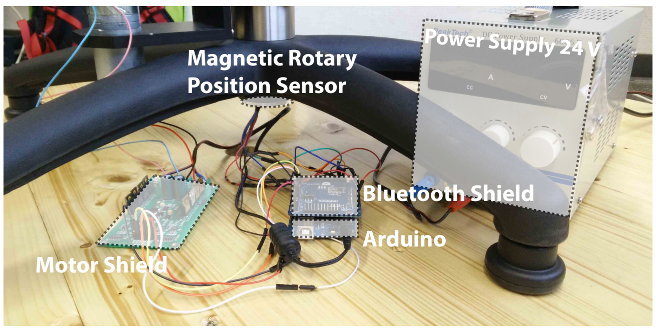

Figure 4. The electronic components which were used to power *SwiVR-Chair* and getting rotational commands from the GearVR

RELATED WORK

We grounded our work in the field of Interactive Digital Storytelling and VR motion platforms.

SwiVRChair is motivated by the work of Vosmeer et al. [15]. They present the different levels of engagement a cinema experience has ('lean back'), compared to a game experience ('lean forward'). They argue that 360 storytelling is a combination of both and raises the research question 'can we indeed establish this engagement style that is neither fully lean-back nor lean forward'. SwiVRChair contributes to this exact question and can be seen as an extension of a 'system's' output capabilities and contains new 'potential narratives' as defined by the framework of Koenitz [10]. As for the use of block and rotate, we used the most fundamental primitives SwiVRChair can physically offer, which allows for novel 'Narrative vectors'. One of the early applications of these concepts of story telling to virtual reality was done by Pausch et al. [13].

Most current motion platforms for VR were designed based on the Steward platform [14] offering a six degree of freedom platform mostly driven by six hydraulic cylindric actuators. These platforms were suited for research laboratories [4] but are not suitable for a domestic scenario. Some prior research implemented motion platforms and feedback devices designed for domestic usage. *HapSeat* [6] presented a low cost motion simulation by letting the user experience motion through three force feedback devices (one in each arm and one behind the head). This simplistic approach was also used in *TactileBrush* [8] where a grid of vibrotactile actuators attached to a chair render strokes on the user's back to simulate motion. These systems both leverage the fact that users perceive motion mainly through their visual, auditory, vestibular and kinesthetic system [5, 7], whereas *SwiVRChair* actually moves the users instead of simulating motion. In contrast to *rotovr* [2], *SwiVRChair* does not create a motion platform which is controlled by the user, but instead focuses on the user being controlled by the environment. This is why *SwiVRChair* deliberately abstained from using footrests and artificial controls such as a gamepad, to enable the user to naturally interfere with the rotation.

USER STUDY

Procedure

To measure what impact *SwiVRChair* has on simulator sickness, presence and enjoyment we conducted a user study. We randomly recruited 16 participants (7 female) between 23 and 30 years old (M=26.1, SD=2.0) from our institution. Every participant watched two 360 degree movies we modeled in Unity3D wearing the Samsung GearVR and sitting on *SwiVRChair*. The scenes were watched directly after another (not removing the HMD in between) to have a longer experience (≈6 Minutes). As a baseline condition we used the *SwiVRChair* setup without the motorization allowing the user to rotate freely throughout the whole experience (*Foot Control*). Both the scenes and the motor conditions were fully counterbalanced. Simulator sickness was measured using the RSSQ [9] before and after each motor condition (*SwiVRChair*, *Foot Control*) and presence and enjoyment were measured using the E^2I questionnaire [12] after each motor condition.

The scenes were created based on the lessons learned by Oculus story studio [1]. The first scene took place in a space warehouse having the participant sit on a virtual chair in the center of the scene. A visual guide leads the user through the scene and introduces them to the environment. At the end a power breakdown shuts down the lights of the scene and simulates a malfunction of the virtual chair, turning the user away from an entrance (figure 5 a). The user now has to fight *SwiVRChair* to turn towards the door seeing only the shadow of a creature approaching them from behind. The scene ends with the user being turned towards the creature and virtually punched in the face to end the scene spinning (figure 5 b). The second scene takes place in a forest inside a house of a fairy. The fairy enchants and spins several items (as well as the user) inside her home and brews a magic potion. After enchanting and scaring the user (figure 5 c), the fairy's kettle explodes spinning her and the user out of the house. The whole experience consists of 3 full rotations (360°),6 half rotations (180°) and 18 minor turns (90°).

Results

Simulator Sickness: The simulator sickenss (figure 6 a) was low for both conditions (*SwiVRChair*: M=0.76 SD=4.05 and *Foot Control*: M=3.0 SD=4.40 on a practical scale of -8.44 to 82.04 [9]). However, a Wilcoxon signed-rank tests showed no significance between *SwiVRChair* and *Foot Control* (Z=-0.909, p = n.s.)

Presence and Enjoyment: In the E^2I questionnaire (figure 6 b) participants rated to have a significantly higher presence (Wilcoxon signed-rank test: Z=-2.14, $p<.05$) and enjoyment

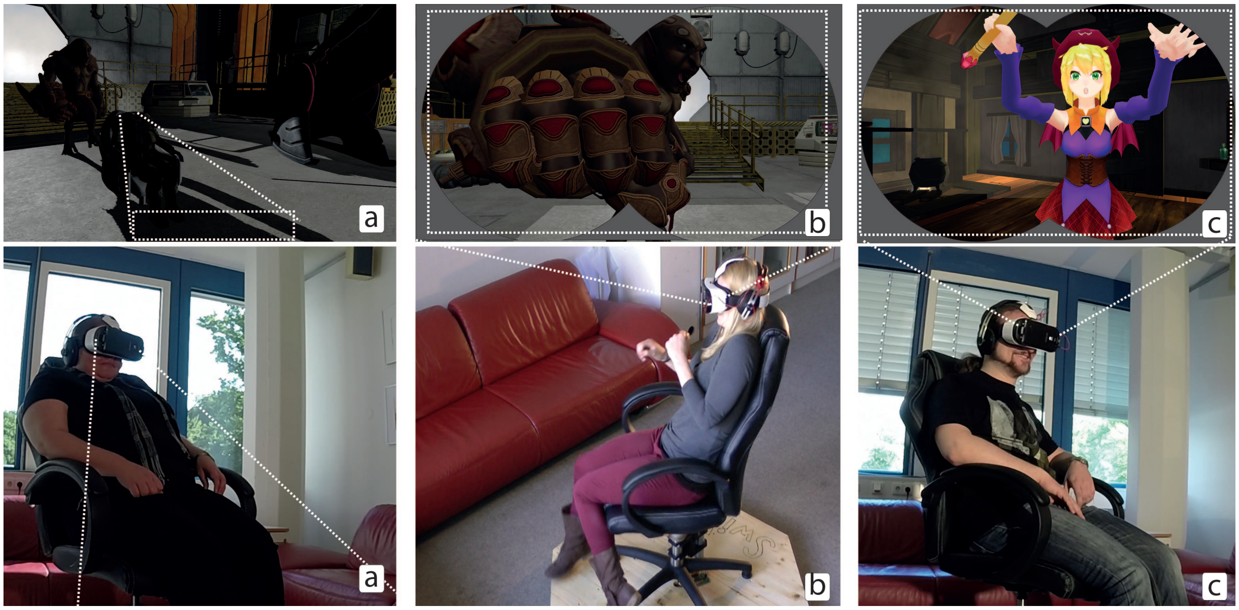

Figure 5. Pictures taken from the users and their emotions during the study, where participants experience the two scenes. a) fighting against the chair b) getting punched by the space creature c) being scared by the fairy.

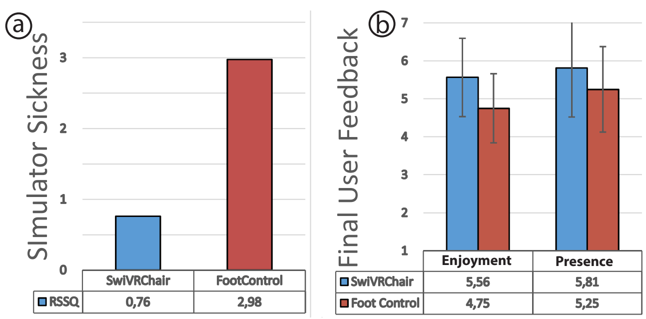

Figure 6. Participants rated enjoyment and presence (b) significantly higher using *SwiVRChair*while having less simulator sickness (a).

(Wilcoxon signed-rank test: Z=-2.80, p<.01) using *SwiVR-Chair* (pre.: M=5.81 SD=0.9, enjoy.: M=5.6 SD=1.0)) vs *Foot Control* (pre.:M=5.2 SD=1.1, enjoy.: M=4.75 SD=1.3).

Usage Data: We measured the overall movement of the head and the chair for both conditions. In addition to the chair movement, participants moved their head more using *Foot Control* (M=2478°, SD=757°) than with *SwiVRChair* (M=2815° SD=1554°). After the study we let participants comment on their experience. Participants reported that using *SwiVRChair*, they "*had a lot of fun*", "*felt comfortable using the device over a longer period of time*" and did not have the pressure of "*missing out on something*". Finally, 14 participants said they preferred using *SwiVRChair*, wanted to have such a device at home and would pay approx 200 *currency*.

DISCUSSION AND CONCLUSION

The overall very low simulator sickness of *SwiVRChair* surprised us as well as the participants. We partially explain this effect with the overall lower head movement of the participants using *SwiVRChair*. Participants were more "*leaning back*" and enjoying the experience and did not have the pressure of having to explore the whole environment to "*not miss anything*". While we offered the ability of always breaking free of the chair's movement participants often did not see the need for it since they got directed towards the relevant content. One can imagine that future 360 degree movies will ideally end up having the same duration as current movies. Having to actively browse the scene and explore the environment for more then 1.5 hours will probably exhaust users. Therefore, we argue that this combination of directional nudging and freedom of exploring the scene offers an important mix of comfort allowing to enhance the experiencing of future 360 degree videos.

In the future, we are planing to systematically investigate the influence of parameters such as rotation speed or rotation distance on the simulator sickness and user experience to generate guidelines of how and where techniques such as *rotate* and *block* should be used in 360 degree movies.

In this work we presented *SwiVRChair*, a motorized swivel chair to control user orientation in 360 degree movies. We introduced the concept of nudging the user's orientation by rotating the chair. We presented how to build *SwiVRChair* and release the source code and building instructions as an open source platform. We presented the results of a user study, showing that participants rated *SwiVRChair* significantly higher in terms of enjoyment and presence compared to *Foot Control* whilst having lower simulator sickness.

ACKNOWLEDGMENTS

We thank Anna Sailer and Christian Weich for the help with the construction. This work was conducted within the Transregional Collaborative Research Centre SFB/TRR 62 Companion-Technology of Cognitive Technical Systems funded by the German Research Foundation (DFG).

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