Using Everyday Sports Equipment as Proxy for Immersive Virtual Reality Workouts

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Figure 1: Rock Climbing in an IVE using a physical rock climbing wall as physical proxy.

ABSTRACT

Virtual Reality (VR) allows users to experience Immersive Virtual Environments (IVE) in a multi-sensory fashion and is making its way into many different fields. Becoming an everyday technology, VR can transform entertainment at home, professional work in the office, and the way users engage in sports activities. The concept of Substitutional Reality maps a virtual environment onto a real one and enables users to physically interact with IVEs, allowing for an increased feeling of presence. In this position paper, we argue that using everyday sports equipment in an IVE as proxies can enhance the users' feeling of immersion and drive them to greater performance. To demonstrate this idea, we will give a brief overview of related work and then describe how a climbing treadmill could be used to simulate vertiginous heights in virtual reality.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; *Ubiquitous computing*; *Haptic devices.*

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EPO4VR'21, May 8–13, 2021, Yokohama, Japan

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ACM ISBN 978-x-xxxx-xxxx-x/YY/MM.
https://doi.org/10.1145/nnnnnnn.nnnnnnn

KEYWORDS

virtual reality, sports equipment, exercise, haptic proxies

ACM Reference Format:
Felix Kosmalla, Florian Daiber, and Antonio Krüger. 2021. Using Everyday Sports Equipment as Proxy for Immersive Virtual Reality Workouts. In *Workshop on Everyday Proxy Objects for Virtual Reality at CHI '21, May 8–13, 2021, Yokohama, Japan.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/nnnnnnn.nnnnnnn

1 INTRODUCTION

Virtual Reality (VR) can be used to trick the user into being immersed into an alternative reality, giving the opportunity for different usage scenarios such as education, training, or simply recreational activities. Although technology has not progressed to the *Ultimate Display* [20] in its completion yet, using head mounted displays (HMD), recent research has shown examples of illusions that go beyond just targeting the visual (and auditory) senses. On the path towards an everyday human-computer interface, concepts evolved that aim to enable immersive experiences in everyday environments, even in the presence of associated spatial restrictions posed by our everyday physical surroundings. Among these concepts, Substitutional Reality (SR) [16, 17] represents the central idea of adapting the experienced Immersive Virtual Environment (IVE) [18] to the physical environment of the user. A virtual space is mapped onto an existing physical space, and real objects are substituted by virtual counterparts. Real objects thereby provide tangibility i.e. passive haptic feedback [5, 6], to the virtual surroundings which improves the sense of presence experienced by the VR user and can be further enhanced by shape changing controllers [15, 24].

In this position paper, we argue that using, more or less, everyday sports equipment in an IVE can enhance not only the feeling of immersion of the users but also drive them to greater performance. First, we will give a brief overview of related work and then present a showcase of how a revolving, indoor rock climbing wall could be used to simulate vertiginous heights in virtual reality.

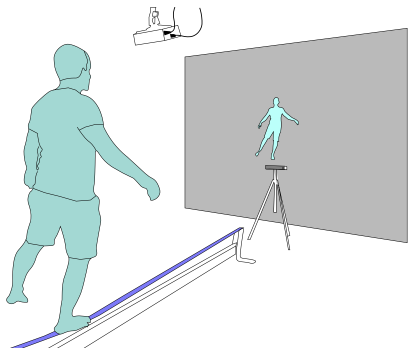

Figure 2: Learning how to walk on a slackline in a projected virtual environment using a physical slackline as proxy [7]

2 RELATED WORK

IVEs in combination with physical training equipment have been explored in several domains. In all examples, the sporting equipment serves as a proxy object to a virtual counterpart in the virtual environment. While most of the examples outlined below use the physical object as proxy for a more or less exact virtual representation of the real world, it could be used to visualize much more sophisticated or engaging equivalents.

Arndt et al. [1] introduced a pilot study in which they used a stationary rowing trainer to simulate a workout on a virtual lake. While they did not find a large difference in performance, their results still indicated an enhanced experience for the athlete in the VR condition. Similarly, however with a projected screen and instead of a HMD, Murray et al. [11] could show that using a virtual environment increased enjoyment and performance. When adding a virtual companion, the performance could be increased even further. In earlier works [7], a projected virtual environment has been used to teach novices how to walk on a slackline. A physical slackline has been used simultaneously as the training equipment as well as the physical proxy. Stationary bikes have been augmented by virtual reality to investigate the influence of visual cues to performance [10], to train road safety[12] or just for fun [2]. Hatsushika et al. waterproofed an Oculus DK2 headset to allow for immersive underwater virtual reality experiences [4]. This enabled scuba diving students to practice diving in potentially dangerous waters in safe and affordable water areas. To overcome the dull, repetitive exercises in a fitness gym, Rabbi et al. presented a VR system using HMDs and motion sensors attached to fitness machines to visualize an engaging IVE [13]. Tiator et al. presented an IVE that allowed for jumping on a trampoline while wearing a HMD [22]. During development, they focused on a low-latency implementation, which resulted in a safe and engaging jumping experience without eliciting simulator sickness. Physical rock climbing walls have been used as physical proxies to allow for immersive climbing experiences. While first works can be seen as proof-of-concept applications [8, 21], later studies investigated the role of physical props on presence, stress, anxiety [14] and the role of visual representation of hands and feet [9].

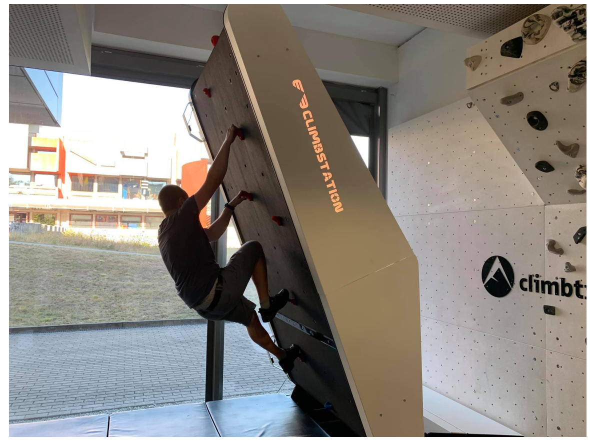

Figure 3: The ClimbStation, a rock climbing treadmill.

Therefore, the use of physical proxies in virtual exercises improves user experience and has the potential to increase the overall performance of a workout.

3 JACK AND THE BEANSTALK

Recent HMD technology allows users to walk freely in a set area that is usually restricted to a room's walls. To overcome this discrepancy between possibly infinite virtual realms and the very finite bounds of a living room, different mechanisms have been developed. Examples for this can be seen in *point & teleport* [3], redirected walking [19], and omnidirectional treadmills [23]. While the first two methods are examples of purely virtual locomotion techniques, an omnidirectional treadmill allows the user to infinitely walk in any desired direction.

This freedom is yet to be seen in virtual reality rock climbing. Currently, the climber is still restricted in the extend of their movement by either the ceiling height or the length of the cable attached to the HMD. In the following, we will outline how these restrictions could be overcome in the future by using a climbing treadmill and the new possibilities this entails.

3.1 Tracking a Climbing Wall

In earlier works [8] we demonstrated how to bring a physical climbing wall into an IVE using and HTC Vive.. First, we created a 3D model of the climbing wall with a Kinect v1 and the Skanect software[1]. This resulted in a dimensionally correct 3D model, however, it lacked detail, especially when it came to hand- and footholds. Nevertheless, the quality deemed 'good enough' to be able to grab

[1]https://skanect.occipital.com/

and step on a hold. To bring the physical wall into the virtual world, a calibration is needed. This is done by defining four distinct points that are easily perceivable on both the physical and the virtual climbing wall, i.e. tips of climbing holds or features of the wall. These real-virtual pairs of reference points are then used to calculate the optimal rotation and translation to match the visual climbing wall with its physical counterpart. This rotation and translation is then applied to the virtual model, resulting in an optimally placed virtual representation that can interact within VR through the physical wall proxy. In this early work, we only tracked the hands of the user by means of a Leap Motion. Later on, we added the tracking and respective visual representation of feet via HTC Vive trackers [9].

3.2 Tracking a Rotating Climbing Wall

With a dimension of 4x3 meters, the climbable area of the climbing wall used above was quite restricted. Using a climbing treadmill such as the ClimbStation[2] allows users to climb infinitely to the top. As with running treadmills, lateral movement is restricted to the width of the belt. In addition to the vertical movement, the ClimbStation is also able to tilt up to -45° degrees to simulate climbing in an overhang.

Being able to use such a device in an IVE allows for numerous applications. One example could be engaging visualizations such as climbing up into the sky on a beanstalk or to scale the face of a sky scraper. Besides entertainment applications, these environments could be used for anti-vertigo training. In contrast to VR experiences in which the user is brought directly to the top of a mountain or building, the illusion of height could be enhanced even more by the ascent itself. Furthermore, the IVE could be used to visualize much steeper overhangs than are actually physically present. This could enhance the feeling of competence and induce a better climbing performance, even outside the IVE.

While tracking a climbing wall with a fixed position in the room mainly entails a mere translation and rotation of the virtual counterpart during the initialization of the program, a rotation climbing wall bears a couple more challenges. The introduced two degrees of freedom have to be tracked continuously during climbing and represented in the IVE. We plan to deploy a set of HTC Vive Trackers attached to the belt and the frame of the climbing wall. While the trackers mounted to the frame are used to detect the tilt, the trackers mounted on the belt will be in charge of tracking the wall's vertical position. Given the belt's planar surface makes a 3D scanning, as in the example of the static climbing wall, unnecessary. However, detailed 3D models of the used hand holds could be used to increase immersion and dexterity during climbing. For this, a mechanism has to be developed to replicate the holds' physical setup in the virtual counterpart.

4 CONCLUSION

In this position paper, we have described how physical sports equipment can be used to enhance virtual reality exercising and vice versa. To illustrate this concept, we outlined how a moving climbing treadmill with two degrees of freedom could be used as proxy to allow for infinite climbing in virtual reality. The use of IVEs in a sports context can be seen as a means of empowering people by altering their perception so that they can overcome psychological barriers to increase their performance ultimately or have a more engaging experience. Future work could study whether everyday objects that are not explicitly designed as sporting equipment could be used as haptic proxies to foster these positive aspects.

[2]https://www.climbstation.com/

5 ACKNOWLEDGEMENTS

This work is partially supported by the German Federal Ministry of Education and Research (16SV8364).

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