Trampoline Jumping with a Head-Mounted Display in Virtual Reality Entertainment

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Abstract. Using a trampoline as a natural 3D user interface with a head-mounted display for virtual reality entertainment is a novel and challenging task. High latencies between interaction and feedback or inaccurate tracking of the user's movement can lead to simulator sickness. In the scope of this project we identified the most appropriate solutions for the described challenge by testing multiple tracking and virtual reality technologies. A fast and precise network-based system was developed using OptiTrack as a tracking solution and Samsung GearVR as a Head-Mounted Display. The introduced system offers an interface to control an application with a trampoline by providing methods to request e.g. the average jump duration or the user's current jump height. In addition, it handles interactions or changes the virtual jump height mapping. Two prototypes were developed, exemplary implementing the interface in gaming experiences. The first application was built to test possible simulator sickness with the Simulator Sickness Questionnaire conducted by 38 users during an in-house exhibition. This evaluation revealed that our system enables a safe and fascinating jumping experience without specific simulator sickness. The second application was built after the initial test to create a more entertaining Trampoline VR application.

Keywords: 3D user interface · Trampoline · Virtual reality
Head mounted display · Prototyping · User tracking

1 Introduction

The arising of high-quality Head-Mounted Displays (HMD) like the Oculus Rift CV and the HTC Vive for non-expert users strengthens the interest in virtual reality (VR) applications. Previous HMD applications often restricted the user's input to gamepads, joysticks or keyboard and mouse. Today's HTC Vive and Oculus touch controllers already enhance the VR experience significantly by providing more natural interactions as the user can use his body movements to interact with the virtual environment. Despite this, we also think that multiple other novel and promising input devices might provide different exciting experiences for users. One such novel input device for VR HMD applications might be a trampoline, since jumping on a trampoline would be an intuitive input for a variety of people, regardless of age. Our goal is to

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combine the fun and excitement of this intuitive interaction with state-of-the-art HMD and tracking technologies. Therefore, the experience could be visually enhanced by virtually transporting the user to a more intriguing place like the moon. Additionally, gaming components could be added to the experience to motivate on exercising jumping.

In this work, we present a novel user interface for VR HMD experiences. For this an interface was developed under certain design criteria to control user interactions in the virtual world with a trampoline. This work is structured as follows: First, related work which have already integrated a trampoline as a 3D user interface for virtual worlds are introduced. We describe how our approach differs from the existing projects and illustrate our application and design. At the end, findings gained during an evaluation with 38 participants are discussed and concluded.

2 Related Work

Several contributions discuss trampolines as 3D input devices for virtual content. A well-known approach from the field of 3D user interfaces is JoyMan, an input device for leaning-based navigation techniques [30]. It was designed by mounting a stand on the flexible area of a trampoline. The user can lean towards a direction and moves into this direction in the virtual world. This “Human Joystick” metaphor and the simple mechanical setup provides an immersive and entertaining interface for virtual locomotion using a mini-trampoline as input device [29]. However, JoyMan does not track jumping activities and gestures.

Shiratori et al. [6, 7, 11] developed a system to control a virtual environment with a mini trampoline. The virtual content was displayed with two projectors on the wall in front of the user. For user interaction recognition, Position Sensitive Detectors (PSD) installed beneath the trampoline measured the distance to the trampoline surface. With these measurements, they could derive user interactions like standing, walking or jumping. This way, the user could navigate through a virtual city. This VR system enhanced the motivation for exercises on the trampoline.

In contrast to Shiratori et al. [6, 7, 11], Holsti et al. [3, 4] used a bigger trampoline and the Microsoft Kinect to track user interactions. Instead of a projector, the content was displayed on a monitor to provide visual feedback for the user. They built multiple prototypes to test their system. One application integrated the Kinect camera image to cut the real video input of the user into a virtual scene. In this scene, the user could playfully practice vertical jumping techniques by reaching higher placed virtual platforms. Besides these research projects we also found footage of the game “Kinect Sports” being played with a mini trampoline [1].

Further, [12] created a trampoline jumping simulation for the Oculus Rift DK2. Nevertheless, fast accelerations such as in a jumping simulation without actual movement of the user could often lead to simulator sickness [2, 13].

To our knowledge, there are no other approaches incorporating a trampoline as an input device for VR applications that are experienced with head-mounted devices and full-body tracking.

Among other things, Frinkelstein et al. showed that jumping in VR in a three-sided CAVE can be a movement motivation for people with autism [14]. They developed a so called exergame in which the user must avoid objects that fly towards him. Another motivating VR exergame was developed in [16]. Children with cerebral palsy should do exercises with and without virtual reality. The results indicated that fun, measured by a visual analogue scale, repetitions and range of motion was higher with VR. [14, 16] showed that children can profit from VR exergames but there also projects that focus on exergames for elderly players [22, 23]. Both projects showed that games can be motivating.

In contrast to the above-mentioned CAVE-based exergames, [15] developed a HMD-based VR exergame. They attached a bicycle to a bike trainer and let the user cycle down to a virtual suburban street. With gesture input detected by a Microsoft Kinect, the user must throw newspaper into neighbourhood mailboxes. Basis for such an exergame could be design guidelines specified by [17, 19]. Interestingly, [17] interpret the criteria of immersion of gameflow [18] in exergames, such that players should control the game with their movements to achieve a high immersion. Additionally, the user should perceive appropriate feedback [18]. In a VR application with body movements, like jumping on a trampoline, control and feedback could be given by a moving avatar. Similarly, [20] showed that using an avatar in a virtual world with head and body tracking can strengthen the effect being in the virtual world because changes that follow rules of everyday sensorimotor contingencies are satisfied. Finally, Frameworks like FAAST [21] make it possible to steer an avatar in conventional games through body movements. Additionally [24] mentioned that immersion could be increased when using an HMD rather than a 2D display or an expensive CAVE.

3 Application and Design

First, the design criteria for the integrated components are described. Afterwards, we elaborate on our system and application implementation.

In our approach, we wanted to integrate a trampoline as a 3D user interface for head-mounted VR systems, where the user is motivated to move. Nonetheless, the usage of a HMD for jumping interactions yields multiple challenges and must be implemented with care. Primary design requirements are: (1) optimizing low latency tracking of the user's head and sufficient precision to enable a joyful experience without the arising of simulator sickness. Additionally, (2) the safety of the user and feeling of confidence in the system while jumping must be considered and supported. Furthermore, (3) provide sufficient multimodal feedback including a visual representation of the user based on tracking data to appropriately control jumping motions on a trampoline and increase the feeling of presence. In this work, we focus on the design and development of the basic framework to prevent simulator sickness and provide the feeling of safety for the user. The first aspect is tested by a standard questionnaire and the latter is validated by informal interviews.

3.1 Component Selection

For our use case, the two most influential components in the setup, which may produce simulator sickness, are the tracking system and the HMD. Thus, both components had to be selected with care and the requirements of the user experience in mind.

One very important aspect is to provide a wide range of user interaction space so that the user can jump on the trampoline without movement restrictions. Therefore, the tracking system must provide a sufficiently sized tracking area. This is especially important when considering elastic ropes as an addition for the trampoline, enabling an even higher jumping area for the user. Besides the enhanced jumping height, elastic ropes can provide the user a surface to grab on and enhance the sense of security when being immersed by the HMD. The visualization of the user's own body as avatar is important for the experience and has a significant impact on immersion, security and simulator sickness because it provides a more consistent view related to the real world where the user sees his body.

For the HMD, the most important properties for us were a high display frequency and resolution, as well as fast and precise head orientation tracking because of the jumping motions. However, the weight and comfort of the HMD placed also a design requirement, as the jumping motions can easily slip the HMD out of place or hurt the user on abrupt landings and can diminishing the presence in the virtual world noticeably. To quickly evaluate the possibilities, we tested different combinations of tracking systems and HMD's by ourselves (self-tests).

We started our technical development with the Oculus Rift DK2 HMD and the Microsoft Kinect v2, as the Kinect was already successfully incorporated by Holsti et al. [3, 4] for a trampoline user interface with great interaction space. Moreover, the Kinect provides a flexible markerless tracking of the whole body and gesture recognition. In our initial self-tests an avatar controlled by the Kinect tracking data mirrored the user's movement in a simple virtual environment with a trampoline reference at the ground. The benefits of a wired HMD are to access the power of a workstation to render images at a high frame rate and to ensure a fast data transport.

Aside from that, we noticed the disadvantage of dealing with the HMD cable, because the immersion is constrained by the anxiety of damaging the cable and its vibrations. In addition, during the test of the combination of Kinect's body tracking and Oculus we experienced massive headache through motion sickness, because joints can flip away and maximum sensor update rate of 30 Hz [25] from Kinect may cause high latency followed by simulator sickness while moving on the trampoline. In our mind, this solution was not appropriate for HMD VR experiences. As the cable of this solution was disruptive and the tracking was not sufficient, we expand our design criteria to use a wireless system with a more accurate tracking, such that joints will less flip away.

Hence, OptiTrack was considered as a tracking system with the Samsung S6 GearVR as a HMD, see Fig. 1. OptiTrack generally provides a wide interaction area, a high tracking frequency, low latency and sub-millimetre accuracy in an optimal setting [9]. Our OptiTrack setup included the Prime13 cameras. In contrast to the Kinect, OptiTrack requires markers on the user's body for tracking. We decided to use five rigid bodies with markers placed on the user's head, hands and feet. Thus, the user is not put through the effort of wearing a complete tracking suite. The rigid body tracking in conjunction with inverse kinematics already provides a sufficient avatar tracking for our use case.

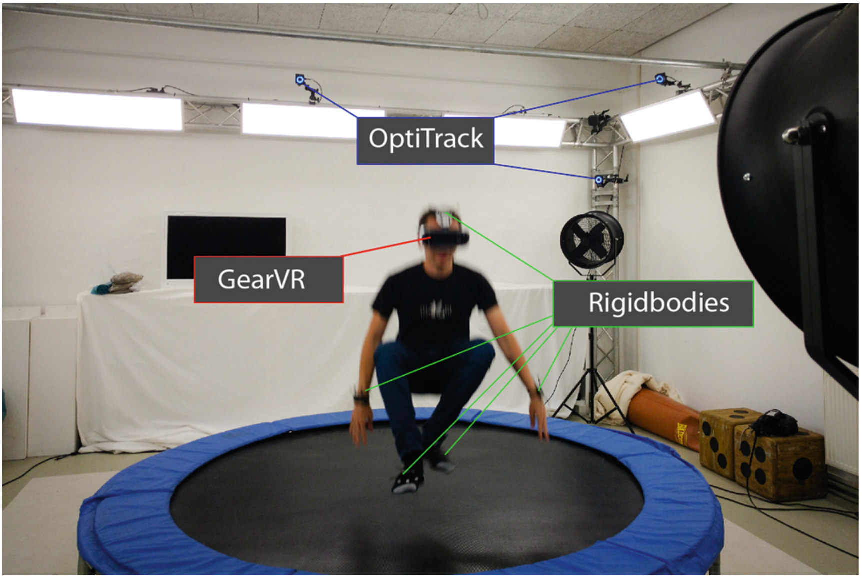


Fig. 1. Final setup: OptiTrack and GearVR. User performing interaction gesture on the trampoline by bouncing in a seating position. Fans in background are not used.

Regarding the HMD, the performance of rendering images is constrained by the smartphone's hardware and inferior to a workstation. Since OptiTrack data is transported via WLAN to the smartphone, the technical setup is fully wireless, providing greater exploration space for the user.

The Neuron Perception motion capture system combined with the Samsung S6 GearVR is another possible wireless solution, that can fit the design criteria. The suit contains multiple Inertial Measurement Units (IMUs) and sends the IMU data wireless to a workstation redirecting it to the HMD. In comparison to OptiTrack, Neuron Perception is not restricted to an area, but only to the range of the network. It is also independent of lighting conditions. As the trampoline stays indoors at a fixed position, these advantages are not relevant for our use case. Moreover, in our self-tests the tracking with Neuron Perception was less precise and had a higher latency, which is a disadvantage for the trampoline jumping scenario with HMD. The acceleration sensor of the smartphone offers another possibility to map the users jumping height. Nonetheless it is not possible to retrieve additional body movement information to map a virtual avatar. Therefore, this solution was disregarded.

In summary, we have chosen the GearVR and OptiTrack, because this setup is wireless, provides an appropriate tracking space and enables a virtual avatar representation because we can calculate body joints based on the marker tracking. During the self-test with this combination we experienced no simulator sickness but decided to conduct a user study on this. Using a Samsung S6 GearVR as a HMD results in a higher resolution than the Oculus Rift DK2, appropriate head orientation tracking, appropriate display frequency with a moderate weight and wearing comfort. OptiTrack also supported the lowest latency and most precise tracking during the self-testing. In addition, the rigid bodies and the GearVR are easy to put on. With OptiTrack we can use elastic ropes to provide more security as well. Finally, we think this system fits our design criteria and users may have a joyful experience without the arise of simulator sickness. For this publication, we decided to focus the user testing on simulator sickness.

Fig. 2. Evaluation setup with elastic ropes. User in a belt jumping in a seating position to avoid the next incoming space ship obstacle.

3.2 System Overview

The OptiTrack cameras are attached to a traverse built around the trampoline, see Fig. 1. The cameras are connected to a PC workstation running the optical motion capture software Motive to calculate positions and rotations of rigid bodies. The tracking data is sent via broadcast to the GearVR via WLAN. This data is used to control a virtual avatar based on an inverse kinematic module adapted from the Unity3D asset store. We set the origin of the virtual world coordinates at the middle of the trampoline's surface and calibrated the system with this centre. After calibration, the user has only to put on the HMD, which is already equipped with a rigid body, and one rigid body for each foot and hand. In total, we need only to track five rigid bodies to control an avatar with inverse kinematics. To initiate and start the game, the user must perform a T-pose at the centre of the trampoline. This way, the virtual avatar gets scaled and adapted to the user's proportions by considering the positions of the head, hands and feet. The whole workflow was recorded as video tutorial so that others can use the trampoline as a 3D user interface as well.

3.3 Implementation

The system was implemented with the Unity3D game engine, because it provides easy integration for multiple hardware and fast prototyping possibilities. Regarding the connection between OptiTrack and Unity3D, the implementation in [10] was integrated. However, recently OptiTrack released a Unity3D plugin themselves [8], which we would recommend for future developments.

Within Unity3D, a small framework was built to supply numerous parameters and methods to use the trampoline as a user interface. Consequently, the trampoline can easily be implemented for prototypes developed in Unity3D. First, the framework provides methods to request the current state of the user. This way, developers can check if the user is currently standing, jumping up, floating in the air, falling or landing. The framework derives these states by analysing the user's velocity and current position in relation to the initial calibration position. In addition, it is possible to retrieve various data about the user's jump. Thus, developers can request measurements like current acceleration, velocity, jump height, average jump durations, average jump heights, lowest jump or the highest jump. For instance, this data could be integrated to create high-score lists or build levels with an adjusting difficulty depending on how high the user can jump. Furthermore, the framework offers an interface to use multiple interaction features: e.g. bouncing in a seating position or running gestures while jumping. Additionally, parameters calculated by the interface can be used to create new interactions.

Besides the described data and interaction options, various perspective views and virtual avatars can be displayed. For instance, the user can switch between camera views like first person, third person, aerial perspective or a view in front of him. This offers exciting possibilities to investigate how perspectives influence the experience in VR. Moreover, diverse forms of virtual avatars can be applied. We distinguish between no avatar or avatars which have only hands and feet, full body but static, full body with fixed animation or full body with inverse kinematics. The fixed animation avatar uses the state information of the framework to play predefined animations depending on the user's current state (for instance a jumping animation is played when the user is jumping). The inverse kinematics avatar is steered by the user's hands and feet. To move the avatar's body according to the user, the head translation is used and mapped to the whole body: If the head is moving to the left, then the body is also moving to the left.

With this simplified setting, the virtual avatar gets controlled with only five markers (hands, feet and head). We found through self-tests that this method is a good approximation to map the user's movements, but it might not be appropriate for more complex movements like deforming the whole body.

3.4 Prototypes

We developed two prototypes with the system to (a) demonstrate, self-test and select different functional capabilities of the framework and (b) to test our primary requirement with this selection: to prevent simulator sickness. The first prototype was an endless-runner Jump 'N' Run game, placing the user in a lava scenery, see Fig. 3. By jumping with an offset of 25 cm from the origin to the left or right side, the user switches between three lanes. With power-ups placed in the scene, the user gains a temporary speed or jump height boost. The speed can also be raised by performing running gestures while jumping. Bouncing in a seating position resets the speed. Other gaming elements like collectable coins and flaming obstacles extends the experience. Besides switching lanes to avoid obstacles, the user can also shoot water out of his wrists to extinguish the fire obstacles.

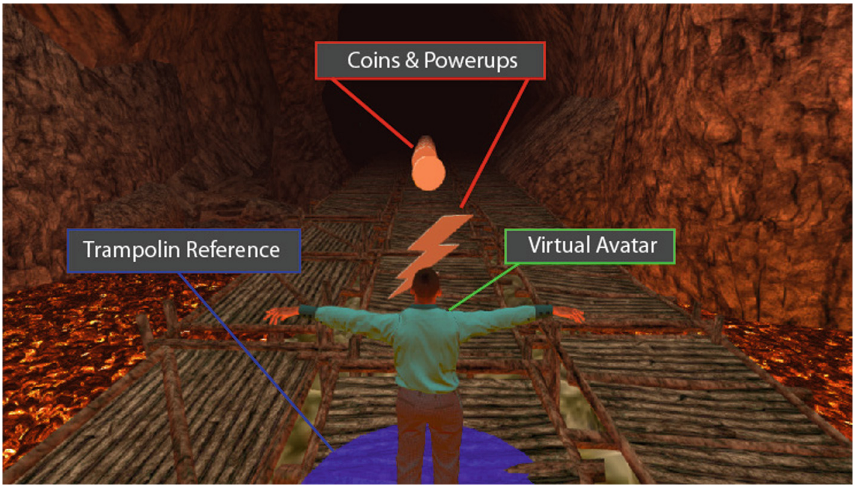


Fig. 3. Endless-runner prototype: lava scene with virtual avatar in 3rd person perspective controlled by inverse kinematics.

The second prototype immerses the user in a space scenario, see Fig. 4. In this VR experience, we added elastic ropes as a necessity for the system composition. With this setup, the user should get into a belt with elastic ropes mounted on a traverse wrapping the trampoline. Then, after an initial calibration that matches a virtual avatar to the user's body, the user plays a walk-though tutorial on how to interact in the game. Like the "avoiding space objects task" in [14], the user's task in this experience is to prevent different space ships from attacking him. This is accomplished by jumping or ducking and thus avoiding the obstacles. In addition, approaching meteoroids are collectable with hands to score points. After a certain number of meteoroids have been collected, it is possible to activate a laser beam by clapping hands together. This way, a wave of obstacles gets destroyed. A high-score for collected meteoroids and increasing the level of difficulty enhance the game and should increase motivation. The perspective view and the virtual avatar representation can be altered by swiping horizontally or vertically on the GearVR's touchpad. We added a virtual trampoline reference to the scenes, so that the user has a better feeling of orientation in the scene. Simple gestures like clapping hands and stretching the arm towards objects allow for some interactions in the scene and provide audio-visual feedback (digital effects, sound, etc.).

Fig. 4. Space prototype: jumping over incoming space ship obstacles.

4 Evaluation

We tested the space prototype during an in-house exhibition with 38 non-expert participants (Fig. 2). As we experienced in the self-tests headache, for example while jumping with Kinect and HMD, we want to explore, if persons perceive simulator sickness with our solution, containing OptiTrack and GearVR. For measuring simulator sickness, we choose the simulator sickness questionnaire (SSQ) [5] like [27, 28]. We hope to get an average score of maximum 10, this should correspond to a simulator which produces minimal symptoms [26]. Moreover, we try to create a fun experience which we, however, do not measure in this case. In each test, we helped the participant to climb into a belt attached to elastic ropes and to put on the rigid bodies and the HMD. During the game, we observed most participants making fast movements, to jump away from the space ships. It seemed like they were immersed by the game, not afraid to move and experienced a lot of fun. Depending on the participants' skill level, the duration of one game was approximately between five and eight minutes. After finishing the game, the participants answered the SSQ. They could choose none, slight, moderate and severe for each item of the SSQ (Table 1). In addition to the SSQ, we asked for the age, experience with VR, susceptibility to nausea (e.g. when driving roller coaster, same ratings as ratings of SSQ items). The users had also the opportunity to leave a comment describing the pros and cons of our application. The participants do an average of 4 (SD = 2.7) hours of sports per week. 32 people had already experience with VR. The average age of the participants was 29.3 years (SD = 8.7), ranging from 17 to 53. The average susceptibility to nausea was 0.81 (SD = 0.87). The results of the SSQ are illustrated in Fig. 5. With the weights described in [5], we obtain the mean values Nausea = 17.57, Oculomotor = 16.16, Disorientation = 29.67, Total = 22.83. Few items of the SSQ were highly rated, although participants visually seemed not to feel strong simulator sickness. For instance, we think that item 5 (difficulty focusing) could generally be highly rated due to a slightly slipping HMD during fast jumping motions.

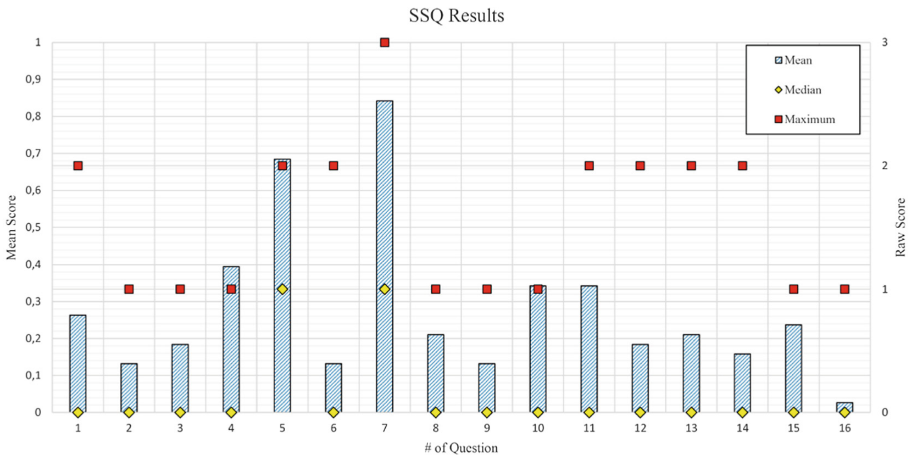


Fig. 5. SSQ results without weighting (Scores: 0 = none, 1 = slight, 2 = moderate, 3 = severe).

Table 1. Items of the SSQ [5]

# of question	Item	# of question	Item
1	General discomfort	9	Difficulty concentrating
2	Fatigue	10	Fullness of the head
3	Headache	11	Blurred vision
4	Eye strain	12	Dizziness with eyes open
5	Difficulty focusing	13	Dizziness with eyes closed
6	Salivation increasing	14	Vertigo
7	Sweating	15	Stomach awareness
8	Nausea	16	Burping

Further, participants might have increased item 7 (sweating) values because jumping on a trampoline is an inherently physically demanding activity. Some participants negatively mentioned the virtual avatar mapping. For example, they commented it like “The virtual character doesn’t quite correspond with the real person.”. Despite this, most of the participants had small or no criticism and did enjoy the experience greatly. They commented the application very positively with notes like “I could’ve actually kept playing, since I didn’t feel uneasy at all. I could freely move myself and had no feeling of spatial restrictions.” or “A whole new adventure thanks to the actual interaction of the body which is fully in charge. Very high fun factor.”. Some participants had so much fun that they even played multiple continuous and exhausting game sessions.

5 Summary and Conclusion

In this work, we described a novel approach for HMD experience by using a trampoline as a user interface. The system benefits of the fast and precise OptiTrack tracking system and the wireless GearVR, which fit our design criteria. With this setup, we achieved an exciting experience and provided a wide interaction area for the user. It is also possible to switch between in-game references and thus to examine if an avatar is increasing the presence. In our opinion, the avatar provides more safety while moving on the trampoline, because when one jumps on the edge of the trampoline, one gets appropriate visual feedback about body location which might be not given when there is no avatar. Furthermore, we think like [20] that a self-avatar which is controlled by real tracked body movements can provide higher immersion in sense of being in the virtual environment and embodiment such that we perceive direct visual feedback to our movements. Also, Holsti et al. [3, 4] displayed the user in the game, such that user sees his own movements on the screen. Concluding that, a VR trampoline system could benefit when visualizing user’s movements in the game. Although the development of the second prototype did not consider game flow criteria [18] by explicit design, it might be helpful to design games with them, when VR-applications should be joyful. We evaluated the system with the SSQ like [27, 28] and although rapid jumping motions are present and the finally score was greater than 10 we noticed most people did not feel specifically simulator sick. Reasons for a high SSQ score could be SSQ items like sweating coming from exhaustive jumping on the trampoline as sport activity. Another reason could be difficulty focussing when the HMD moves a little bit while jumping. The opinion that the participants feel low simulator sick although the SSQ score was high is strengthen by the participants' positive comments and their exhaustive movements. According to that, our system could possibly be an appropriate platform for more advanced motivating exergames. Finally, the target groups from [14, 16, 22, 23] and middle-aged people could also benefit from this work. We summarize our design decisions for an expressive VR trampoline experience as follows:

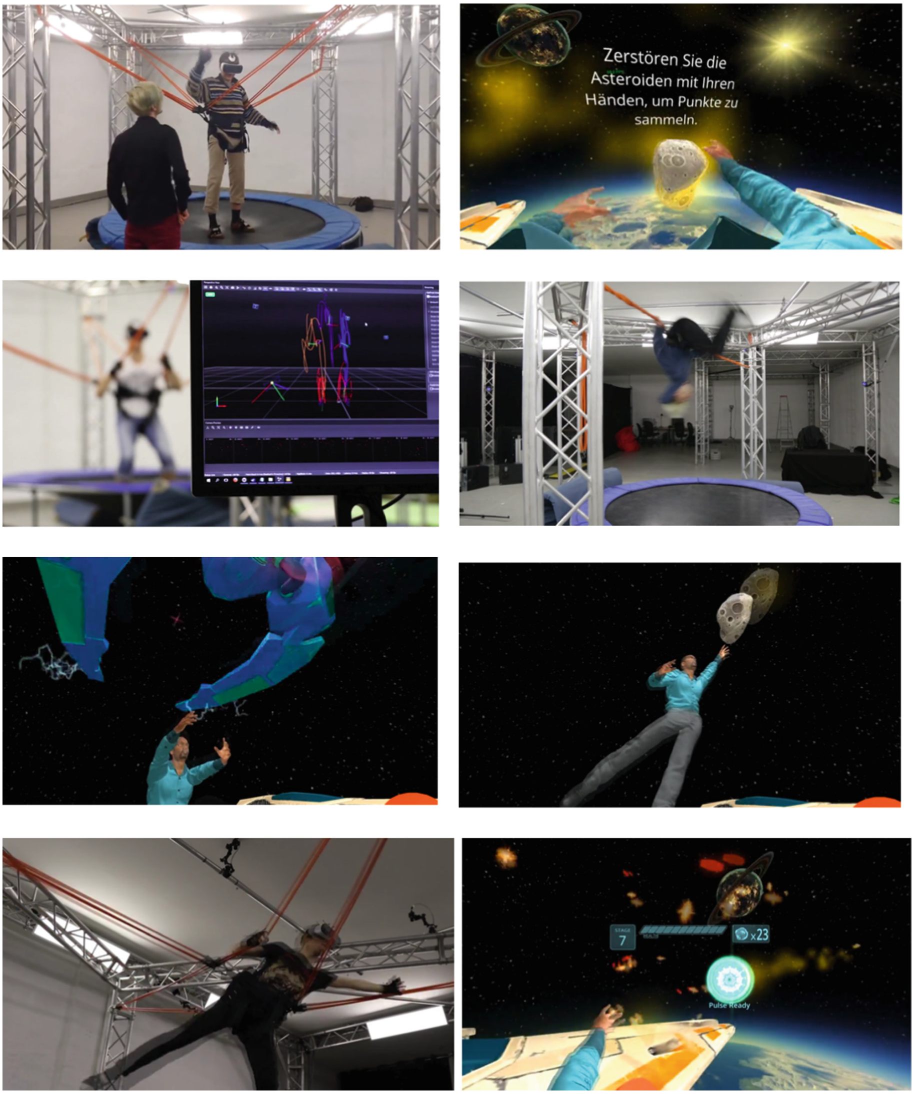
- For jumping activities and fast-moving user actions the trade-off between a high-end tethered VR device and a wireless system has been considered based on the user's actions. We decided to use a mobile setup using GearVR as the best compromise.
- For best orientation, the user's body needs to be visualized in a believable way. This requires a full-body tracking in the size of the space covered by the trampoline and of at least 5 tracking positions on the body (Head, hands, feet) if an appropriate inverse kinematic module is used. We decided to use a high-end marker-based tracking system (OptiTrack).
- Consider a minimal instrumentation of the user and provide safe play conditions. Help the user to understand the required interactions while jumping with a head-mounted VR device. We created an in-game tutorial and use elastic ropes to support this.
- Design the game based on a flexible and robust framework in a way that minimizes simulator sickness and maximizes joy of use. We designed a simple game that supports jumping activities and tested the application using a standard questionnaire for simulator sickness (SSQ). For this publication, we validated the joy of use only by self-testing and informal user feedback after the formal SSQ test.

For future work, wind machine feedback for fast-moving Jump 'N' Run games could enhance the immersion. Additionally, we would like to investigate more forms of interactions and experiences, like musical interfaces or other gaming concepts. Further, we want to study which form of avatar representations (Sect. 3.3) provides most security, embodiment, enjoyment and immersion for users. We will further investigate appropriate methods for measuring those features. As we experienced through self-tests, it is possible to use an avatar to provide system feedback to the user. It would be interesting to identify how different perspectives and avatars (Sect. 3.3) affect the interactivity and user experience. Thus, the presented work offers multiple possibilities for further user experience research.

Video

A video showing the system in action during an exhibition is available at https://vimeo.com/200660539, switch on cc to read the english text.

Selected Impressions from the System Prototype



References

1. Glenn, J.: Kinect Sports Hurdles on Trampoline for Plyometrics (2015). https://www.youtube.com/watch?v=VIxSi3stVvs
2. Google: Designing for Google Cardboard - Physiological Considerations (2016). https://goo.gl/tqqO62
3. Holsti, L., Takala, T., Martikainen, A., Kajastila, R., Hämäläinen, P.: Body-controlled trampoline training games based on computer vision. In: CHI 2013 Extended Abstracts on Human Factors in Computing Systems, CHI EA 2013, pp. 1143–1148. ACM, New York (2013)
4. Kajastila, R., Hämäläinen, P.: Motion games in real sports environments. Interactions **22**(2), 44–47 (2015)
5. Kennedy, R.S., Lane, N.E., Berbaum, K.S., Lilienthal, M.G.: Simulator sickness questionnaire: an enhanced method for quantifying simulator sickness. Int. J. Aviat. Psychol. **3**(3), 203–220 (1993)
6. Mori, H., Shiratori, K., Fujieda, T., Hoshino, J.: Flexible foot interface for versatile training field. In: SIGGRAPH 2009: Posters, SIGGRAPH 2009, p. 99:1. ACM, New York (2009)
7. Mori, H., Shiratori, K., Fujieda, T., Hoshino, J.: Versatile training field: the wellness entertainment system using trampoline interface. In: ACM SIGGRAPH 2009 Emerging Technologies, SIGGRAPH 2009, p. 25:1. ACM, New York (2009)
8. OptiTrack: OptiTrack Unity Plugin (2016). http://wiki.optitrack.com/index.php?title=OptiTrackUnityPlugin
9. OptiTrack-Support: General FAQ (2016). http://optitrack.com/support/faq/general.html
10. ozzyonfire: UnityOptiTrack - Github repository - A test project to get Optitrack streaming into Unity 3D without using a DLL (2014). https://github.com/ozzyonfire/UnityOptitrack
11. Shiratori, K., Mori, H., Hoshino, J.: The trampoline entertainment system for aiding exercise. In: Proceedings of the 8th International Conference on Virtual Reality Continuum and Its Applications in Industry, VRCAI 2009, pp. 169–174. ACM, New York (2009)
12. thebko: Trampolake Unity Demo for Oculus DK2 (2014). https://www.youtube.com/watch?v=y6tnnrIVwUI
13. OCULUS VR: OCULUS Best Practices (2016). https://static.oculus.com/documentation/pdfs/intro-vr/latest/bp.pdf
14. Finkelstein, S.L., Nickel, A., Barnes, T., Suma, E.A.: Astrojumper: designing a virtual reality exergame to motivate children with autism to exercise. In: 2010 IEEE Virtual Reality Conference (VR), Waltham, MA, USA. IEEE (2010)
15. Bolton, J., Lambert, M., Lirette, D., Unsworth, B.: PaperDude: a virtual reality cycling exergame. In: CHI 2014, Toronto, Ontario, Canada. ACM (2014)
16. Bryanton, C., Bossé, J., Brien, M., McLean, J., McCormick, A., Sveistrup, H.: Feasibility, motivation, and selective motor control: virtual reality compared to conventional home exercise in children with cerebral palsy. CyberPsychology Behav. **9**(2), 123–128 (2006)
17. Tanaka, K., Parker, J.R., Baradoy, G., Sheehan, D., Holash, J.R., Katz, L.: A comparison of exergaming interfaces for use in rehabilitation programs and research. J. Can. Game Stud. Assoc. **6**(9), 69–81 (2012)
18. Sweetser, P., Wyeth, P.: GameFlow: a model for evaluating player enjoyment in games. ACM Comput. Entertain. **3**(3), Article 3A (2005). ACM
19. Sinclair, J., Hingston, P., Masek, M.: Consideration for the design of exergames. In: GRAPHITE 2007, Perth, Western Australia (2007)

20. de la Pena, N., Weil, P., Llobera, J., Giannopoulos, E., Pomés, A., Spanlang, B., Friedman, D., Sanchez-Vives, M.V., Slater, M.: Immersive journalism: immersive virtual reality for the first-person experience of news. Presence **19**(4), 291–301 (2010)
21. Suma, E.A., Lange, B., Rizzo, A.S., Krum, D.M., Bolas, M.: FAAST: the flexible action and articulated skeleton toolkit. In: IEEE Virtual Reality 2011, Singapore. IEEE (2011)
22. de Bruin, E.D., Schoene, D., Pichierri, G., Smith, S.T.: Use of virtual reality technique for the training of motor control in the elderly. Zeitschrift für Gerontologie und Geriatrie **43**(4), 229–234 (2010). Springer-Verlag
23. Brox, E., Luque, L.F., Evertsen, G.J.: Exergames for elderly. In: 5th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) and Workshops (2011)
24. Reiners, T., Teräs, H., Chang, V., Wood, L.C., Gregory, S., Gibson, D., Petter, N., Teräs, M.: Authentic, immersive, and emotional experience in virtual learning environments: the fear of dying as an important learning experience in a simulation. In: Proceedings of the 23 Annual Teaching and Learning Forum 2014, University of Western Australia, Perth, Australia (2014)
25. Microsoft: Kinect-Hardware (2017). https://developer.microsoft.com/de-de/windows/kinect/hardware
26. Kennedy, R.S., Drexler, J.M., Compton, D.E., Stanney, K.M., Lanham, D.S., Harm, D.L.: Configural scoring of simulator sickness, cybersickness and space adaptation syndrome: similarities and differences? NASA Johnson Space Center, Houston, Texas, USA (2001)
27. Ferdous, S.M.S., Arafat, I.M., Quarles, J.: Visual feedback to improve the accessibility of head-mounted displays for persons with balance impairments. In: IEEE Symposium on 3D User Interfaces 2016, Greenville, SC, USA. IEEE (2016)
28. Fernandes, A.S., Feiner, S.K.: Combating VR sickness through subtle dynamic field-of-view modification. In: IEEE Symposium on 3D User Interfaces 2016, Greenville, SC, USA. IEEE (2016)
29. Pettré, J., Siret, O., Marchal, M., Lécuyer, A.: Joyman: an immersive and entertaining interface for virtual locomotion. In: ACM SIGGRAPH ASIA Emerging Technologies (e-Tech), Hong-Kong (2011)
30. Marchal, M., Pettré, J., Lécuyer, A.: Joyman: a human-scale joystick for navigating in virtual worlds. In: Proceedings of the IEEE Symposium on 3D User Interfaces (2011)