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Physically Compressing Virtual Reality Environments

Through modern technology, virtual reality (VR) is able to connect people with computer-generated, augmented reality. VR allows people to walk around and experience a virtual environment by wearing special eyewear and tracking devices. These virtual environments could include outdoor areas, roads, offices, apartment buildings, or practically anything else that humans can experience in physical reality. One of the most important components of virtual reality is the freedom it gives to its users to explore and interact with the virtual world. This freedom should allow users to walk around without restrictions and without having to stop because of a physical limitation. By having the opportunity to utilize a limitless, unrestricted physical environment, the virtual environment being experienced is even more realistic. Unfortunately, a limitless, unrestricted physical environment is not feasible in our physical reality. There is a finite amount of physical space allocated to any virtual world, even though the virtual world can be of any size. Therefore, in order for a virtual reality to be feasible in a physical world, there needs to be a change in the boundaries and technologies utilized.

In the past, there has been research of different methods of allowing people to move freely in a virtual world; these include using multidirectional treadmills and bicycles. Although those methods worked, they were not very effective in creating a realistic virtual world. The main problem behind the ineffectiveness of these methods lies in the lack of the innate walking motion. The physical motion of walking on a floor is recognized by people intuitively, and is thus the ideal motion to use when interacting in virtual worlds. The solution to this problem can be found by compressing the virtual world so that it better fits into the available physical space. There are many ways to compress a virtual world, and the two papers I have chosen each discuss different ways to do so. The first paper, written by T. C. Peck, H. Fuchs, and M. C. Whitton, describes one method of compressing virtual reality by using an interface that was designed to detain people within the physically available space. [1] The second paper, written by K. Vasylevska and H. Kaufmann, explores many different methods of compressing virtual reality and describes the benefits and drawbacks of each. [2]

Peck, Fuchs, and Whitton's paper, titled, "Improved Redirection with Distractors: A large-scale-real-walking locomotion interface and its effect on navigation in virtual environments", was published in 2010 in *IEEE Virtual Reality Conference*. This paper describes an interface called Improved Redirection with Distractors (IRD). IRD works by altering the user's view in a way that causes them to move in a radial pattern, circling towards the center of the physical space. IRD is able to alter the user's view without their knowledge, so they perceive themselves walking in a normal manner. By always having the user move towards the center of the space, IRD decreases the physical size of the virtual world. Without the use of the IRD interface, users would move further away from the center when taking a turn. Keeping the user closer to the center when turning allows them to have more flexibility for further movements. [1]

Despite the extra space provided by the IRD interface, it is still possible for the user to move to the edge of the physically available space. However, the IRD interface was designed to correct this by using a "distractors" component. When the user moves to edge of the available space, the IRD interface presents them with a distractor to direct their attention away from the correction the IRD will make. While their attention is with the distractor, the virtual world changes so that the user is pushed back towards the center of the physical space, away from the edge. In the experiment presented in the paper, the distractor used was a ghost. The users were instructed to close their eyes and shake their head if they saw a ghost. The ghosts appeared in the virtual reality whenever a user was too close to the edge of the physical space. Therefore, when they closed their eyes, the virtual world could change, unknowingly to them, and redirect them into the physical space once they opened their eyes again. [1]

The IRD interface was determined to be highly effective at compressing the size of a virtual environment. With the IRD interface at play, users are able to navigate in the virtual world as easily as they are able to navigate the physical world. One negative result of the use of the IRD interface is the increase in the user's physical walking. Another negative aspect of the IRD interface is the interruption caused by the distractor algorithm that is used. Although this could be improved, the IRD interface is still effective in creating an overall realistic virtual reality experience.

The other paper is titled, "Compressing VR: Fitting Large Virtual Environments within Limited Physical Space", and was published in *IEEE Computer Graphics and Applications* in 2017. It came seven years after the first paper, so it discusses and expands upon many other methods of compressing virtual reality. Although the IRD interface is referenced in this paper, it is only one of the many examples provided. The simplest method discussed alerts the user when they reach the edge of the physical space and asks them to walk back to the center. While this method solves the apparent problem, it is very intrusive and breaks the virtual reality experience. There are more subtle and effective methods of centering the user in the available space than this simple method. An effective and highly flexible method is rendering manipulation, which alters the rendered image to conform with the available physical space. However, a huge drawback is that it can alter the virtual environment so much that many of the original visuals are lost. [2]

The method that this paper mainly focuses on involves manipulating the virtual images so that the user naturally stays in the available physical space. By using optical illusions, the user is tricked into thinking different spaces are the same size when in reality they are not. This method changes the scene when the user is not looking, similar to the distractor in the IRD interface. For example, the door to a room may be moved to a different wall so the user will move in a more desirable direction towards available space. Surprisingly, not many users notice the change in the scene when their attention is regained to the changed area. Another technique renders spaces that are not physically possible. For example, two adjacent rooms may have a large overlapping portion; therefore, they can take up less space because part of their physical footprint is shared. To share the space, hallways can be constructed so that the user is disoriented and does not notice that the two rooms are built in a way that is not physically possible. The research determined that the more complex the hallways were, the less the user noticed about the illusion that was being displayed. Straight hallways were found to be the least effective, “U-shaped” hallways were slightly more effective, and “C-shaped” hallways were most the effective because of the complexity of their shapes. Additionally, corridors and hallways that had asymmetrical layout were more convincing than those that were symmetrical because it was more difficult for the user to remember a pattern. [2]

Both of the papers that I reviewed offered methods for compressing the physical space of virtual reality worlds. The paper published first, “Improved Redirection with Distractors: A large-scale-real-walking locomotion interface and its effect on navigation in virtual environments”, only looked at one method for solving this problem. However, this paper was published in 2010 when virtual reality was much less prevalent and less developed than it is today. Despite this, it did discuss the IRD interface in more detail than any method presented in the second paper. They discussed quantitative results of their studies, which the other paper did not. The paper published more recently, “Compressing VR: Fitting Large Virtual Environments within Limited Physical Space”, discussed many different methods, but in relatively little detail. Although they lacked extensive details, the methods they discussed are more realistic when thinking about how virtual reality is used today.

References

[1] T. C. Peck, H. Fuchs, and M. C. Whitton. Improved redirection with distractors: A large-scale-real-walking locomotion interface and its effect on navigation in virtual environments. In *2010 IEEE Virtual Reality Conference (VR)*, pages 35–38, March 2010.

[2] K. Vasylevska and H. Kaufmann. Compressing VR: Fitting large virtual environments within limited physical space. *IEEE Computer Graphics and Applications*, 37(5):85–91, 2017.