TranSection: Hand-Based Interaction for Playing a Game within a Virtual Reality Game

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Abstract
TranSection is a new VR interface design concept with cross-dimensional virtual reality interface. It is a 2D puzzle platformer game within a 3D virtual environment. By incorporating the head tracking and visualization capabilities of Oculus Rift and hand tracking capabilities of Leap Motion, TranSection enables realistic interaction with virtual objects through one's own hands. Our evaluation with 12 participants showed that players rated the fun level as 4.17 on a 5-point Likert scale, and 83% of the players would like to play TranSection again. The cross-dimensional interface also significantly reduced simulator sickness, which is one of the critical usability barriers to using virtual reality, compared to the highest rated puzzle game on Oculus Rift.

Author Keywords
Oculus Rift; Leap Motion; Virtual Reality; simulator sickness; immersion;

ACM Classification Keywords
K.8.0 [Personal Computing]: General Games.

Introduction
With the advent of low-cost virtual reality (VR) headsets such as the Oculus Rift, VR comes into the consumer's reach. To build a more immersive household VR

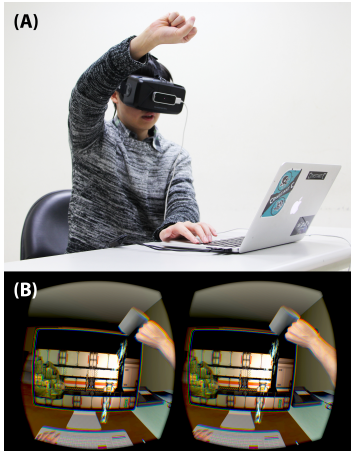

Figure 1: Leap Motion mounted onto the front of Oculus Rift to build virtual environment of TranSection. Cross (a)The player grasped the virtual cup by natural movement.(b) Water was poured from 3D virtual reality to 2D virtual world.

Figure 2: In 3D virtual reality, we embed virtual computer to build another 2D virtual world.

experience, lots of motion controllers are collocated with VR headsets. Hand-based motion tracking devices such as Leap Motion[1], Move[3] and Wii Remote[5] are the most frequently used motion controllers with VR headsets because they are easily available and inexpensive. Hand-based motion tracking devices as natural user interface (NUI) enable players to grasp and manipulate the virtual objects providing immersive VR game experience.

To enhance natural user interface in 3D VR, we proposed and implemented a cross-dimensional virtual reality interface that empowers 2D immersive interface in 3D VR. TranSection is a fully immersive puzzle game that places a player into a virtual environment where he himself becomes an in-game character manipulating virtual objects with his own hands to solve a series of mysteries in a 2D puzzle platformer game.

Immersive game interface

Hand-based motion tracking devices provide natural user interfaces (NUI) which mediated a feeling of presence in the digital world to enhance game immersion[6]. However, the affordance of natural user interfaces to perform abstract commands in VR is limited because body motion has bonded with avatar motion in VR. For instance, users exit a game in VR by opening a 2D pop-up menu and selecting exit button which is GUI but not NUI, thus breaking both consistency of interface and immersive game experience. We demonstrated an example to enhance NUI affordance and to keep interface consistency in VR by exploring a cross-dimensional virtual reality interface under the hand-based motion tracking device and the VR headset. We constructed a virtual environment that was presented to the players by a wide-FOV Oculus Rift Development Kit 2 (DK2)[2] and sensed users' interaction with Leap Motion[1](See Figure 1).

Cross-dimensional virtual reality interface

Traditionally, motion tracking devices translate natural movements to direct manipulation of 3D virtual objects in full-immersive 3D VR. We proposed a cross-dimensional virtual reality interface to enable immersive 2D interface manipulation in VR rather than 3D immersive manipulation. Our cross-dimensional virtual reality interface embeds a virtual computer which contains a 2D virtual world and keyboard within VR and empowers the player to use the virtual keyboard by means of the real world keyboard(See Figure 2). Based on the concept of multi-layer game design from ATUM[7], cross-dimensional virtual reality interface enables a new design space that interacts with 2D virtual environments in 3D VR with virtual objects including the avatar's body, objects in game and a virtual keyboard. This new dimension in VR enriches the game experience, even the player's avatar stays at a fixed position in the 3D VR world. Previous work[9] show that decreasing the visual flow which means graphic changing slow would relieve simulatorsickness, so cross-dimensional virtual reality interface could deal with this problem. By showing a 2D GUI in the virtual computer within VR we exploit the real world metaphor that a GUI usually appears on a screen instead of in the air, cross-dimensional virtual reality interface keeps the interface of a game consistent. On top of that, the objects in different dimension can interact with each other; for instance, in our game, a monster breaks out from 2D screen into the 3D world and a 3D knife can be used to attack the monster on the 2D screen.

Design and Development

In TranSection, designing a game is challenged by the fact that the entertainment experience might be disrupted by the sickness symptoms; thus, our design aims for relieving as much symptoms as possible by playing on a seated

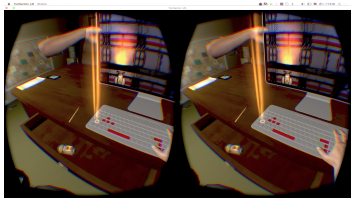

Figure 3: Virtual feedback showing from virtual keyword to hint the player which ineffective key is pressed

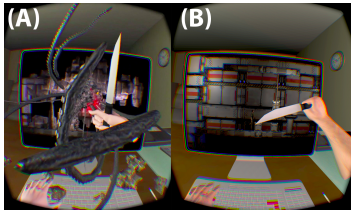

Figure 4: Each of the virtual objects is endowed with versatile functionalities. Using a knife to (a)stab monsters or (b)cut the rope.

position, rather than standing or walking. While the practice of design involves more than consideration for intuition and learnability, what makes the player access the computer and control the in-game character within the 3D virtual environment is creating a virtual keyboard that maps to the position of the real world keyboard and shows the indicative animation above the button when it is pressed(See Figure 3).

In this game, we were also very interested in exploring and identifying how people interact with a variety of different virtual objects; therefore, we experimentally adopted some multiple-scale objects such as a matchstick, a knife, and a cup which lead to various types of grasp gestures.

In addition, we addressed common hand interaction by decoupling these two aspects: one is the pre-contact grasp-recognition phase which gives robustness to users at initial grasping, and the other is the post-contact delicate manipulation phase after grasping a virtual object; furthermore, we propose a strategic and yet straightforward algorithm which can achieve more robust grasp-recognition and delicate manipulation. The idea behind our grasp-recognition algorithm is detecting the intersection of two to five small rectangular boxes which are attached to each fingertip. The algorithm can also be employed when the player spreads his or her hand to release an object; as a result, the object will be returned to its original position.

Gameplay and Mechanics

TranSection initially places the player character inside a desolate office seated in front of a desk on which several virtual items sit. He then receives a mysterious invitation for playing a game via email. Suddenly, a man appears on the virtual computer screen and is trapped inside. The players goal is to assist the man to find a way out by solving virtual computer puzzles. Once the player starts controlling the mans movement via keyboard within the sci-fi platformer game, the man will stumble upon monsters and obstacles which need to be confronted by utilizing virtual items in the office. For example, the player character should grab a mug filled with water from his office desk and pour water onto a fire presented in the virtual computer screen in order to put it out so that the man is able to continue walking through a level(See Figure 1). Another example is that a player uses a knife to stab monsters that crawl out of the computer screen(See Figure 4). Each of the virtual objects has versatile functionalities. For examples, not only can one light a match to ignite an inflammable barrier, but one can also illuminate a dark wall hiding a password that unlocks a door. For another example, the knife can be used for both defeating monsters and cutting ropes. The game ends in finding an exit for the man. However, a trap is set by the man that results in an exchange in position of the two characters. The man is freed and is now in the office while the player character gets trapped in the platformer game. The ending of this game should be surprising and should leave endless imagination to the player.

Evaluation

In order to investigate our game experience, we separated our experiments into two parts: interestingness and simulator sickness (SS). For assessing the experienced fun after playing with TranSection, we adapted the extended Short Feedback Questionnaire(eSFQ)[10], which investigated the enjoyment, curiosity and co-experience of games. TranSection is a single-player game; therefore, we removed the questions about co-experience in eSFQ to fit for our game. For evaluating SS after playing with our game, we used the Simulator Sickness

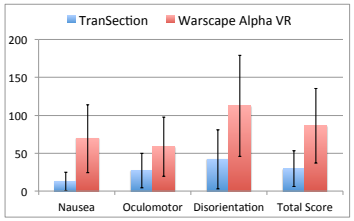

Figure 5: The means of the four SSQ metrics of TranSection and Warscape Alpha VR

Questionnaire(SSQ)[8], which contains metrics for the severity of simulator sickness experienced by the users of VR systems. To validate whether our game design would decrease SS, we compared the SSQ scores of TranSection with another Oculus puzzle game in the same category as TranSection. We selected Warscape Alpha VR[4] as the control group, which is the highest rated puzzle game in Oculus VR Share. In total 12 participants, 5 females and 7 males, the mean of the experienced fun level for TranSection was 4.17(SD = 0.94)(5 meaning Yeah, fun and 1 meaning Yawn, boring). 83% of the players indicated that they wanted to play the game again. The curiosity about TranSection was rated with a mean of 4.33(SD = 0.9) (5 meaning very curious and 1 meaning not curious at all) The results from the eSFQs show that our TranSection game interface design is practical and interesting.

In respect of SS, the SSQ means of TranSection were lower than the means of Warscape Alpha VR in all metrics(see Figure 5). There are significant score differences in each of the SSQ metrics: Nausea($F_{0.05}(1, 10)=17.58$, $p = .00003$), Oculomotor($F_{0.05}(1, 10)=5.8$, $p = .00248$), Disorientation($F_{0.05}(1, 10)=10.01$, $p = .004499$) and Total Score($F_{0.05}(1, 10)=12.85$, $p = .001651$). The results from SSQ show that our game interface relieved the simulator sickness effect.

Conclusion

TranSection contributes to the development of a fully immersive puzzle game through a novel interface that uses precise hand motion tracking combined with a head-mounted tracking system and display. In the process of designing TranSection, we explored the design space of hand-based interaction in VR and then proposed a "cross-dimensional virtual reality interface" which enables a 2D virtual interface within a 3D VR. This enables a new design space in VR without breaking the immersion whilst relieving the simulator sickness.

Acknowledgements

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