Save the Space Elevator: An Escape Room Scenario Involving Passive Haptics in Mixed Reality

Shakiba Davari, Yuan Li, Lee Lisle, Feiyu Lu, Lei Zhang, Leslie Blustein, Xueting Feng, Brianna Gabaldon, Marc Kwiatkowski, and Doug A. Bowman*

Center for Human-Computer Interaction, Department of Computer Science, Virginia Tech

Abstract

This paper presents our solution to the 2019 3DUI Contest challenge, which focuses on passive haptics. We aimed to provide a compelling user experience in virtual reality while overcoming the limitations of physical space and current tracking devices. To meet these goals, we designed a time travel scenario that incorporates several novel features. A time machine increases efficiency in the use of physical space. A passive haptic camera prop provides a help system that is integrated into the storyline. Finally, the concept of a "temporal stabilizer" provides a plausible way to reuse a single tracking device to track multiple passive haptic props.

Keywords: 3D interaction, passive haptics.

Index Terms: H.5.2 [Information interfaces and presentation]: User Interfaces. – Interaction techniques

1 Introduction

Understanding 3D spaces and performing actions in free space are often difficult for people [1], and traditional interaction styles and techniques may not lead to a realistic and compelling user experience [2]. Passive haptics are a low-cost and powerful way to provide realistic shape, weight, and texture stimuli in virtual reality (VR). For the 2019 3D User Interfaces contest, we designed a 3D UI which covers multiple interaction features, using passive haptics in an underlying escape room scenario. These features include rotation, insertion, joining, squeezing, and identifying the attributes (e.g., geometry and weight) of an object. We crafted an underlying escape room story to make the transition among the selected tasks fluid.

Our design draws from real-world interactions, science fiction, and existing 3D UI techniques. It combines them in a coherent narrative that is novel, aesthetically pleasing, and easy to learn. It effectively uses both limited physical space and technological resources.

2 Design Process

Our design process started with multiple group meetings dedicated to brainstorming ideas for the overarching story and individual puzzles for the VR escape room. Next, the team divided into four groups that focused on story, art, passive haptics, and software. During our bi-weekly meetings, guided by an overarching story document that we iterated on throughout the process, the team explored interaction techniques for different tasks, determined devices to use, and discussed early prototypes. Our discussions covered different topics including strategies for addressing the requirements, implementation strategies, modeling, fabrication and assembly of the passive haptics devices, data transfer strategies, and tracking.

We decided early on to use an HTC VIVE Pro head-worn display with Lighthouse 2.0 tracking and a wireless adapter. This setup provides high resolution and accurate tracking, and does not tether the user to the computer, allowing for freedom of movement. We also decided to employ two HTC VIVE Trackers to track passive haptic props as the user interacted with them. Props were either constructed from existing objects or designed as 3D models and printed using a 3D printer.

3 Escape Room Scenario: Save the Space Elevator

Our overarching narrative is a future scenario involving time travel and a critical mission that must be carried out by the user. In the year 2258, an Electromagnetic Pulse (EMP) device destroys a database needed for the construction of a space elevator, which is critical to humanity's plans of establishing a colony on the moon. The user is cast as an agent from the secret Federal Bureau of Time Corrections. Their objective is to time travel between the present time and the past and solve different puzzles in the two time periods that will lead to the discovery of a memory cube, which can be inserted into the central computer in the past to disable the EMP before it goes off. The agent needs to complete the mission before their body's temporal radiation limit is met. If they succeed, the space elevator plans will be saved.

This story gives context and urgency to the solving of the individual puzzles, establishes a reason for the user to find and use all the passive haptic interactions, motivates the time limit, and allows us to reuse the same physical space for two different virtual spaces.

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4 Key Design Elements

4.1 Time Machine

To stop the EMP explosion, the agent is granted access to a "time machine" in the form of an airlock which is triggered automatically when the agent walks inside. Due to limited energy supply, the machine can only carry the agent between two different time periods. This element allows us to reuse the same physical space with different virtual layouts. This helps increase the efficiency of the design and overcome the limited physical space available for the experience.

4.2 Hint Camera

We also needed a way to facilitate usage and learning of the system but did not want to break the user experience with an explicit "help system" or intervention by a system operator. Instead, we developed the notion of a camera provided to agents that would detect objects in the scene related to the EMP and memory cube. Through this magic lens, objects of interest are

* {sdavari | yli92 | llisle | feiyulu | leiz | leslie6 | fairyfxt | bgab21 | Kwiatkowski22 | dbowman} @vt.edu

highlighted, and hints are provided in a way that is integrated into the storyline.

Throughout the experience, the user holds a physical 3D printed camera prop with a VIVE Tracker attached at the position of its lens (Figure 1). The camera prop resembles its virtual counterpart and enables the user to identify the object's attributes such as weight and geometry.

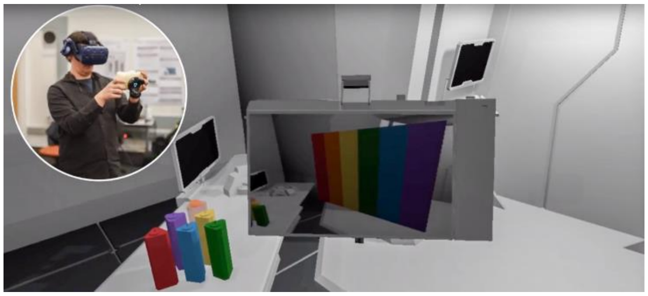

Figure 1: The user holding the designed passive haptic prop for the camera to get hints for solving the candle puzzle.

4.3 Temporal Stabilizer

To address the challenge of tracking the physical passive haptic props and connecting them to their virtual representation, HTC VIVE Trackers are used. However, since we have four props (Figure 2) and only one free tracker (one is used for the camera throughout the experience), we needed a way to reuse the same tracker for multiple props without breaking visual-haptic consistency. We designed the story so that the user interacts with only one of the props at a time. We then introduce the tracker to the user as a "temporal stabilizer," saying that it needs to be attached to objects to activate them and make them safe to be handled. The tracker and each physical prop are outfitted with weak magnets that allow the tracker to be attached at a precise position and orientation. Using a wizard-of-Oz approach, an operator notes when the tracker has been attached to a particular prop and presses a key to attach the virtual model of that object to the tracker.

4.4 Puzzles

4.4.1 Candle Puzzle

Six candles of different colors are arranged on a table. The user must light all the candles using a blowtorch in the correct order of the white light spectrum.

The user must activate the blowtorch by squeezing its physical object's nozzle. A swim noodle that can easily be squeezed is used as the blowtorch nozzle (Figure 2-c). By squeezing the blowtorch, the Bluetooth button embedded inside the nozzle will be pressed which will signal the virtual blowtorch to be lit. Once lit, each candle's illumination will change to exhibit its expected appearance. Through the hint camera, the user can see a rainbow above the candles, which will help them light the candles in the correct order.

4.4.2 Tic-Tac-Toe Puzzle

The user must return the missing piece of a Tic-Tac-Toe game to its proper place on the board. The piece is a 3D printed object. By holding the piece, the user can feel the geometry and weight of the object and identify the physical object's attributes.

4.4.3 Switch Puzzle

The agent needs to simultaneously hold down two switches. The user can stand on one switch, but they must realize that they can hold down the other one using the weight of the physical camera.

4.4.4 Valve Puzzle

The agent must find a valve (Figure 2-d) on the floor and insert it into a pipe. Then the user rotates the valve to get hot water through the pipe.

4.4.5 The Final Puzzle

Completing each of the puzzles reveals a special object called a *cryptex piece* to the user. The cryptex pieces are four 3D printed cylinder pieces (Figure 2-b). Once all four cryptex pieces hidden in the two different time periods are collected, the agent must correctly align and join them together in a final stacking puzzle to discover the *memory cube*. Once the agent finds the memory cube in the present time, they must travel back in time to insert it in the 3D printed placeholder (Figure 2-a) and deactivate the EMP explosion.

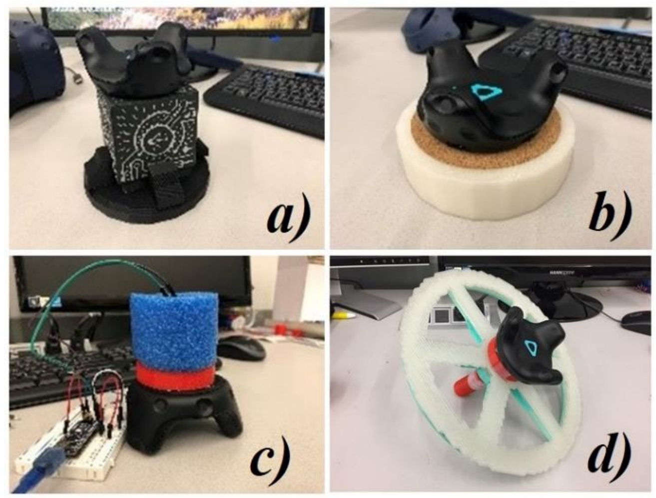

Figure 2: The designed passive haptics props for puzzles. a) The memory cube inserted in its placeholder. b) A cryptex piece. c) The blowtorch. d) The valve.

5 Conclusion

We designed a 3D UI using interactive passive haptics to provide a compelling VR escape room experience. Our design offers a coherent underlying scenario to make smooth transitions between different tasks and keep the user engaged. Our design includes novel elements that reuse the same physical space for two virtual rooms, reuse the same tracking device with multiple passive haptic props, and provide hints to the user through an integral story element.

References

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