Pyramid Escape: Design of Novel Passive Haptics Interactions for an Immersive and Modular Scenario

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Abstract

In this paper, we present the design of ten different 3D user interactions using passive haptics and embedded in an escape game scenario in which users have to escape from a pyramid in a limited time. Our solution is innovative by its modularity, allowing interactions with virtual objects using tangible props, either through a direct manipulation of the hands or the feet, or re-using a single prop in the hand to perform several interactions with the virtual environment (VE). We also propose a navigation technique based on the impossible spaces design to maximize the size of the VE, allowing users to navigate by natural walking in the VE through several overlapping rooms. All together, our different interaction techniques allow the users to solve several enigmas into a challenging scenario inside a pyramid.

1 General Description

Passive haptic scenarios significantly enhance virtual environments (VEs) [1]. However, allowing the succession of many passive haptics interactions in one scenario remains challenging due to the distinctive feature of each interaction. In this paper, we present the design of ten different 3D user interactions using passive haptics. They are embedded in an escape game scenario in which users have to solve enigmas to go from one room of a pyramid to another until they finally find the exit. The ten different user interactions, further described in Section 3, are the following: rotating, inserting, pressing, pushing, joining, squeezing, identifying the attributes of an object, throwing, sliding and human-touch feedback. They all include passive haptic feedback, either through a direct manipulation of the hands or the feet, or by re-using a single prop in the hand to perform several interactions in the VE. The main characteristics of our design is the re-usability of the same prop for several interactions as well as the use of our hand-held prop to mediate the interaction with other tangible props, each constraining the user's movement and providing adequate physical feedback to the hand. In addition to the manipulation techniques, we used the "impossible spaces" design [2] to maximize the size of the VE, allowing users to navigate by natural walking in the VE through several overlapping rooms. All together, our different interaction techniques propose an exciting modular scenario composed of several enigmas to escape a pyramid.

2 Apparatus

Users are immersed in the VE using a head mounted display. Their feet and hands are tracked by two HTC Vive trackers and a Leap Motion. The location of each static tangible object is set and known at anytime according to a first calibration phase. They are fixed on the ground or a table and their position and orientation are registered using a Vive tracker fixed to a calibration prop which can be plugged onto the other props. The navigation space is 2 by 3 meters.

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3 3D User Interactions

As a scenario, we propose an escape room game inside a pyramid. The user has to solve several enigmas in four different rooms inside the pyramid. We designed ten different user interactions involving passive haptics and described in this section in a chronological order.

3.1 Pushing

Users start the adventure lying down on the ground without seeing anything in the VE. They were told that they were in a sarcophagus and their first interaction is thus to push the top of the sarcophagus to get out of it. In the real environment, they actually push a lid made of cardboard attached to a light structure surrounding them (see Figure 1, left pictures). Users are then attracted by a light emitted by a scepter that they are supposed to grab and that they will further use to interact with the VE. In the real word, the scepter is a 3D-printed object which will be the main prop used to perform physical interactions with other tangible props (see Figure 1, right pictures).

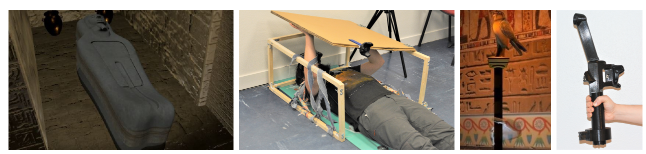

Figure 1: (Left) pushing the sarcophagus (virtual and real), (Right) the main prop (virtual scepter and real prop).

3.2 Sliding

With the scepter in hand, users need to find a stone where they can plug the scepter into a hole, allowing them to slide it, which triggers the opening of a door to another room. The prop is made of a fixed runner and a moving part constrained to a single axis translation. The user is able to slide the moving part with the bottom of the scepter and feels a resisting force generated by rubber bands (see Figure 2).

Figure 2: Sliding an object through rails: (Left) virtual environment with the sliding task, (Right) user motion with the real prop.

3.3 Foot-pressing

In the second room, users must find a code on the wall that they afterwards have to enter by pressing on four stone-buttons on the ground with their foot. Physical buttons are made of several layers of foam (see Figure 3). The code opens a door and presents to the users an additional element that they can join to their scepter and that will be required for further interactions in the next room.

Figure 3: Pressing buttons with feet: (Left) virtual representation of the feet and the buttons, (Right) real interaction with the foot.

3.4 Throwing

In the third room, users encounter three containers, including one with fire. They have to collect a fire projectile from this container with the top of their scepter and throw it into the other containers to kindle them. The prop for the throwing task is made of a ping pong ball held into a container and attached with a wire to a counterweight which brings the ball back into the container after it is released. Users are able to pick the ball with the spoon-like part at the top of the hand-held prop, thanks to magnets that attract the metal within the ball. The ball is detached whenever the wire is fully stretched or the prop velocity is fast enough (see Figure 4).

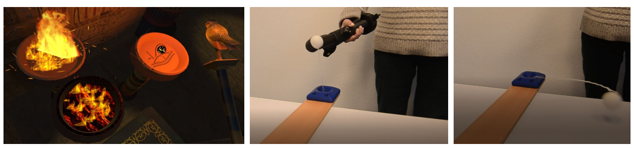

Figure 4: Throwing fire projectiles: (Left) virtual environment with the containers, (Right) details of the real prop for throwing the fire projectile.

3.5 Plugging

Once the throwing task is performed, users see some hieroglyphs on a table that they can grab with the scepter using the additional joined element they obtained in the previous room. The physical prop associated with the hieroglyph is joined to the scepter and then fixed to the support using magnets and variable gaps. The users are thus able to plug each hieroglyph into its corresponding location, which unlocks a rotation mechanism, by physically removing magnetic pins (see Figure 5).

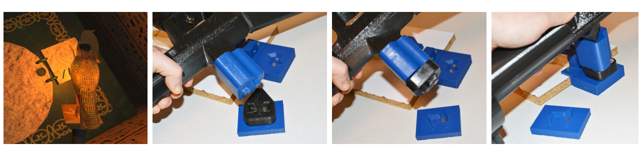

Figure 5: Plugging-in a hieroglyph into its receptacle: (Left) virtual representation, (Right) details for a hieroglyph manipulation.

3.6 Rotating

Users then have to plug their scepter into a hole on a circular plate and make it rotate allowing the movement of a light ray that will illuminate a gem once the correct number of rotations has been performed. The user can plug the lower part of the hand-held prop onto a 3D-printed part fixed to a wooden bar that constrains the rotation around a screw (see Figure 6). The rotation unlocks the door of the fourth room. Before leaving this room, users are invited to put down the scepter, leaving their hands free.

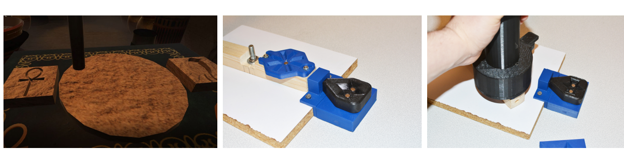

Figure 6: Rotating circulate plate: (Left) virtual representation of the circular plate, (Right) details of the rotation mechanism.

3.7 Squeezing

In the fourth room, users face a table on which there are three receptacles, each receptacle has a button in front of it. Users have to press the buttons in a certain order indicated on a surface covered by milling beetles. To see the order, users must squeeze the beetles with their hand which makes them disappear. In the real world, their hand smashes over bubble wrap to experience a pressure sensation (see Figure 7, left pictures).

Figure 7: (Left) squeezing insects task, (Right) identification of three different materials.

3.8 Material Recognizing

The code indicated on the surface informs of an order between materials contained in the three receptacles. Users cannot see into them, so they have to put their hand into them to recognize each material. In the real world, users put their hand into physical receptacles that contain water, sand or water bubbles (see Figure 7, right pictures).

3.9 Hand-pressing

After the identification of the three materials, users can press the buttons corresponding to each receptacle in the correct order. The physical buttons corresponding to the virtual ones were 3D printed and contain foam to generate a passive pressure sensation (see Figure 8). The resolution of this enigma opens the final door that free the users.

Figure 8: Pressing buttons with hands: (Left) virtual scene with the three buttons, (Right) details of the real buttons.

3.10 Shaking-hand Bonus

Finally out of the pyramid, users face a mysterious pharaoh walking to them. When close enough to the users, the pharaoh extends his arm in the direction of the user, and they can experience a handshake with the physical feedback of the experimenter's hand (see Figure 9).

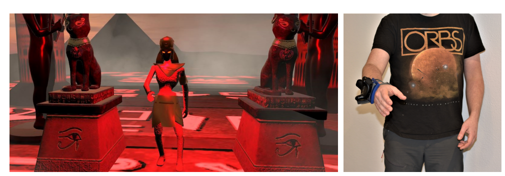

Figure 9: Shaking hands with the pharaoh: (Left) virtual environment with the pharaoh, (Right) experimenter's hand for human-touch feedback.

References

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