
An Encounter Type VR System Aimed at Exhibiting Wall Material Samples for Show House

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Abstract

In this research, we propose a system that can change the tactile material of a wall surface, especially in a virtual reality show house. To present multiple types of wall materials, an encounter-type tactile sense presentation unit with several wall materials mounted on a uniaxial robot presents a specific type of wall material according to the hand movements of the experimenter. With this encounter-type approach, users can experience the tactile sensations of multiple kinds of realistic wall materials. We examined the specifications necessary for such presentation, constructed the system, and conducted a user study to examine the effect of the proposed system, comparing visual-only and visual + force conditions.

Author Keywords

Encounter type; material feeling; tactile display; virtual reality; VR show house.

Introduction

Wall material is an important factor in architecture that characterizes and personalizes individual houses or rooms. Currently, two methods are adopted for wall material exhibition. One is the show house (model room), which is naturally realistic but requires a certain

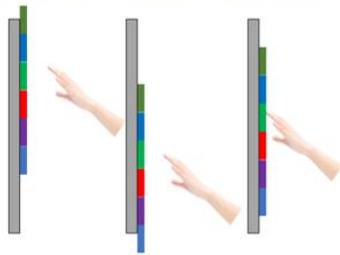


Figure 1: When the user reaches out, the proposed device presents the tactile information (top) of the same material as the wall displayed in the VR space (center). Tactile presentation follows the hand motions

cost and space; moreover, it is almost impossible to display various types of building materials at once. The other way is to use a booklet called a sample book, which consists of several types of building material samples, fragmented and affixed to a book. While it is portable and can display various building materials, it is hard for the user to imagine how it feels when a material is used in a living environment.

For wall material presentation, what is needed is to display many building materials and to show the use image in the room. To satisfy this requirement, we employ a virtual reality (VR) show house. Whereas a VR showroom is a VR environment that presents three-dimensional (3D) images of products (typically using a head mounted display), such as the VR showcase by Audi [2] or the IKEA VR Experience [5], a VR show house is a type of VR showroom that exhibits the house itself in a VR environment. However, although a VR show house can satisfy the aforementioned requirements in terms of visual presentation, there are few VR show houses that can also provide tactile information. In other words, users cannot perceive whether the wall material is soft or hard, rough or smooth, or cold or warm.

In this research, we propose a system for a VR show house capable of presenting the material feeling of a real wall. To present multiple types of wall materials, several wall materials are mounted on and moved by a uniaxial robot according to the hand position of the user. With this encounter-type tactile presentation technique, users can experience the realistic tactile sensation of wall materials. We also conducted a user study to verify that the VR show house experience is clearly improved by our system.

Related Work

Tactile display to present the feeling of a material

Several tactile presentation methods for VR have been proposed. Some used a glove equipped with tactile display modules at the fingertips [4], and others are a gripping type [8]. In addition, there are systems that make it possible to display the feeling of a material when the user traces the surface with a pen using a commercially available pen tablet [9] and a system that displays the material feeling of a floor with a device that presents a sense of touch to the foot rather than the hand [11].

In contrast, a method of presenting a tactile sensation using a real object has also been proposed [6]. This method must actually prepare real objects corresponding to the contents of the VR experience, but it is an appropriate method for presenting a perfectly realistic feel because the user touches the real thing. One method that uses this approach is called an encounter-type VR system. The system uses a device such as a plane, cube, or corner that is moved and rotated to match the position and orientation of the object in the VR space. The encounter-type VR system typically uses a multiple degrees-of-freedom robot arm [10]. Some exceptions include systems that use human hands [3] or a drone [13].

While the encounter-type display is intrinsically capable of expressing all haptics related features, most of them focus on shape: surface properties such as texture are not often considered. Rare exceptions are the Snake Charmer [1] and Haptic Revolver[12], which is capable of dynamically switching the surface texture by rotating the tip of a robot arm or wheel. However, in these



Figure 2: HMD (top) and Vive tracker (bottom) used to reflect the hand position in the VR space.

examples, the touching action is only limited to pushing with the fingertip because of the limited surface area.

In the proposed VR system, a simplified encounter-type haptic display is used to dynamically switch the displayed object. Furthermore, we aimed to design a tactile sense presentation device that can also handle strokes on its surface, which is a typical action when a wall is touched.

Encounter-type VR system for exhibiting wall materials

Tactile presentation device

The simplified encounter-type haptic display developed in this study is shown in Figure 1 and Figure 3. The design parameters such as the speed of the surface and size of the wall were obtained by preliminary experiments.

We used a plywood sheet with a thickness of 4 mm, height of 800 mm, and width of 900 mm. Four kinds of wall materials, each with a height of 200 mm, were affixed to this board to present the tactile sense of the wall material. The materials were aluminum plate, plywood (the base plate), wallpaper with a thin embossed wood pattern, and wallpaper with indented surfaces made of PVC (Sangetsu, SP series). All were easy to discriminate by their texture.

The board was attached to a single-axis robot (Yamaha, FLIP-X series T9H) with a maximum stroke length of 1,050 mm so that the plate moves in the longitudinal direction. We set the movable range of the robot to 1,000 mm. Because the four wall materials are 200 mm in height, the range over which all the wall materials can be presented is 600 × 900 mm, with the exception

of the 600 mm width of aluminum plate. The robot was fixed to wooden posts that were firmly attached to a wall-mounted bookshelf using cable ties.

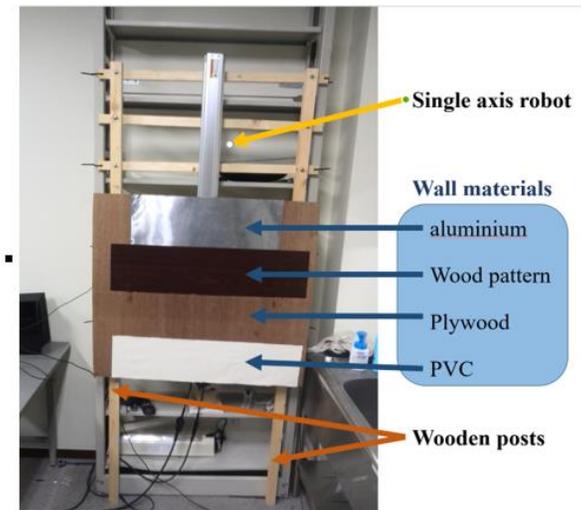


Figure 3: Tactile sense presentation device using a single axis robot that drives a board with wall materials.

System

A head mounted display (HTC, Vive) was used for displaying the VR space (Figure 3). To properly reflect the hand position of the user in the VR space, a Vive tracker (99 HALM005 - 00, HTC) was worn on the back of the user's right hand. Double-sided Velcro tape was wrapped around the hand to attach the Vive tracker. A Unity game engine was used to construct the VR environment, and a hand model and the wall were presented in the VR scene. The height information of the Vive Tracker was transmitted from the Unity program to the single axis controller every 0.1 s to the

control position of the plate according to the hand position.

A VR showroom with four walls, a floor, and furniture was prepared. The area where tactile presentation is possible was designed to protrude from the surrounding wall so it could be easily recognized by the user. We instructed users in advance not to touch the walls outside of this range. The visual appearance of the wall and the kind of the wall material presented by the robot can be switched by keyboard.

During the experience, Unity's program acquires the y-coordinate of the Vive Tracker and converts the height value to the corresponding point value of the single axis robot. This point value is transmitted to the serial communication program using UDP (User Datagram Protocol) communication every 0.1 s. The serial communication program generates the appropriate command statements and transmits the command to the robot controller by serial communication. In this way, the part with the specific wall material follows the height of the hand. When the distance between the hand and the plate becomes less than 1 cm, the robot stops.

User Study

We investigated whether the VR system proposed in this research improves the quality of experience compared to the existing visual-only VR show house experience. We also compared the proposed system with encounter-type tactile presentation without presenting the surface texture to verify the effectiveness of using actual wall material for tactile presentation.

We recruited eight participants (seven males, 22 to 24 years old) from our laboratory. Four types of wall material—plywood, aluminum plate, wallpaper made of PVC, and wallpaper with an embossed wood pattern—were used for tactile presentation. Visual walls corresponding to each material were prepared in the VR space. Two walls were presented in the VR space: a wall displayed at the same location as the tactile device (the haptic wall) and a wall displayed in the air (the non-haptic wall).

We also specified how the wall should be touched. Specifically, the experimenter demonstrated the instructions to the participants. The instructions were as follows: i) "When you touch the wall and stroke, be sure to stroke only in the left-right direction." ii) "If you would like to change the height of your hand on the wall, release your hand from the wall, change the height of your hand, and then touch it again." iii) "Move your hand slowly." The following three tactile conditions were combined for each material, giving a total of 12 experimental conditions.

- Nothing: Participants touched the non-haptic wall.
- No texture: Participants touched the haptic wall, but they wore a thin rubber glove and vinyl gloves to eliminate texture feeling and temperature sensation. The aluminum plate with a slippery surface was used for all tactile presentation. We confirmed that under these conditions, we experienced no irregularities on the surface nor any temperature sensation.
- Texture: Participants touched the haptic wall with their bare hands. The visual and tactile textures were always matched.

During the experiments, the participants were asked to wear headphones playing white noise to mask auditory cues such as those from the robot. The experience time was 20 s per condition.

After the trial, we removed the headphones, displayed the questionnaire in the VR environment, and asked the participants to answer orally. We asked about how realistic the wall in the VR space was (its "realism") on a seven-point Likert scale. All conditions were experienced once in random order.

Results

The results are shown in Figure 4. There was an obvious trend for all wall materials; the No-texture condition yielded a consistently higher score than the Nothing condition, and the Texture condition was better than both. As a result of 1-factor multi-variance analysis using the Dunn–Borferoni method with the wall material type as a condition, we found significant differences between the Nothing and Texture conditions for all wall materials ($p < .005$). We also found significant differences between the No-texture and Texture conditions for plywood and PVC ($p < .05$). There are no significant differences between the results for aluminum and wood grain.

These results confirm that the VR show house, which presents visual and tactile senses, including surface texture, is a more realistic way to present wall material than a visual-only presentation. We also found that for coarse texture in particular, the VR show house is more realistic than a presentation that does not display surface texture.

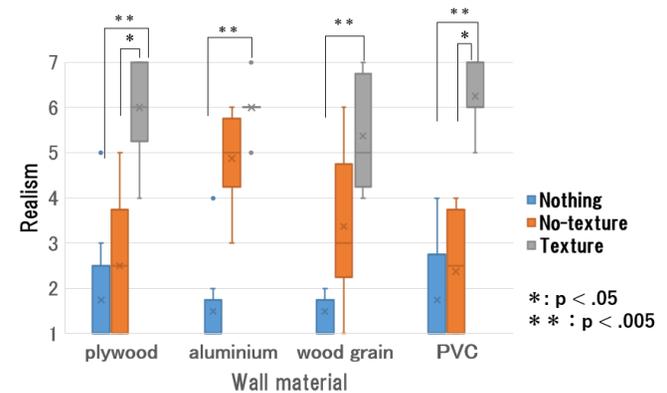


Figure 4: Results of a subjective evaluation of the realism of the wall, classified by each type of wall material.

Conclusion

In this paper, we proposed, developed, and evaluated a method that uses an encounter-type tactile presentation device for a VR show house.

We conducted a user study to determine whether the experience of touching a wall material is improved by our tactile sense presentation system based on a single axis robot. The results confirm that the proposed method improves realism compared with the vision-only case. We also found that the proposed method was more realistic than one that did not present surface texture for coarse texture surfaces.

Our future work includes a study of the number of wall materials needed for tactile presentation in order to cover most wall materials available today.

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