Virtual Whiskers: Cheek Haptic-Based Spatial Directional Guidance in a Virtual Space

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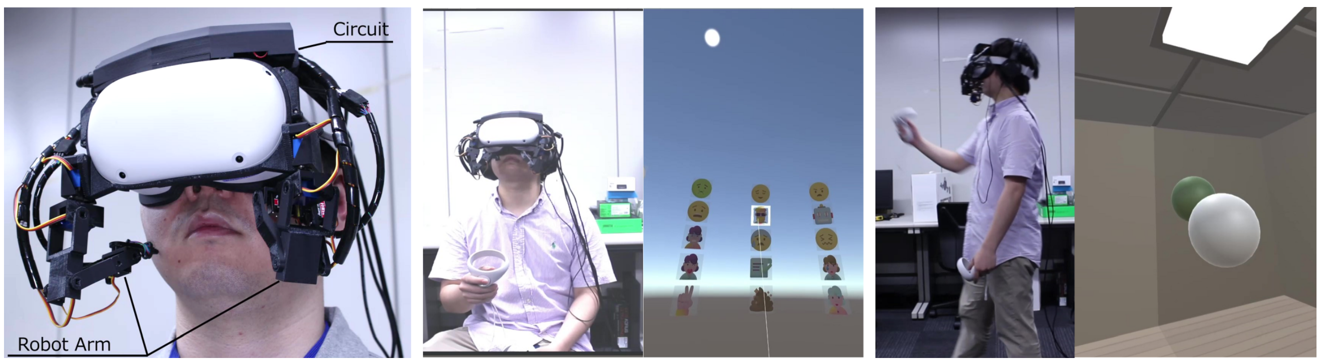

Figure 1: *Left*: Cheek Haptic Stimulation Device. *Center*: Image Finding Application. Users look for a target icon among many icons with the help of cheek haptic stimulation. *Right*: Target Touching Application. Users search and touch approaching targets relying on cheek haptic stimulation.

ABSTRACT

In spatial navigation, adding haptic cues to visual information lets users understand the spatial information better. Most haptic devices stimulate various body parts, while few devices target our heads that are sensitive to mechanical stimuli. This paper presents Virtual Whiskers, a spatial directional guidance technique using cheek haptics in a virtual space. We created a cheek haptic stimulation device by attaching two tiny robot arms to a Head-Mounted Display. The robot arms trace the cheek with proximity sensors to estimate the cheek surface. Target azimuthal and elevational directions are translated into a point on the cheek surface. The robot arms touch the point to present target directional cues. We demonstrate our technique in two applications.

CCS CONCEPTS

• **Human-centered computing** → *Virtual reality*; **Haptic devices**.

KEYWORDS

spatial guidance, cheek haptics, virtual reality, robot arm

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1 INTRODUCTION

Spatial cues are important for spatial navigation in a virtual environment. Most spatial navigation systems leverage visual cues. However, a virtual environment already has much visual information. Adding spatial visual cues can cause visual clutter. Some navigation systems integrate audio cues, but they affect workload. To avoid visual clutter and achieve less workload, haptic cues are used. Most haptic-based guidance techniques focus on the torso and hands, while few studies adopt facial haptics even though the face is one of the most sensitive to mechanical stimuli. Especially if haptic stimuli are on the torso when the head moves, the perceived stimulation position is shifted [Ho and Spence 2007]. In addition, a previous study showed that facial haptics with ambient cues improved virtual experiences [Wilberz et al. 2020]. However, they investigated the only horizontal wind cues in terms of directional perception. Also, their system required the calibration between the robot arm and the user's face by hand.

In this paper, we present Virtual Whiskers, a spatial directional guidance technique in 3D space with cheek haptics. We develop a cheek haptic stimulation device by integrating two robot arms into a Head-Mounted Display (HMD). The robot arms with proximity

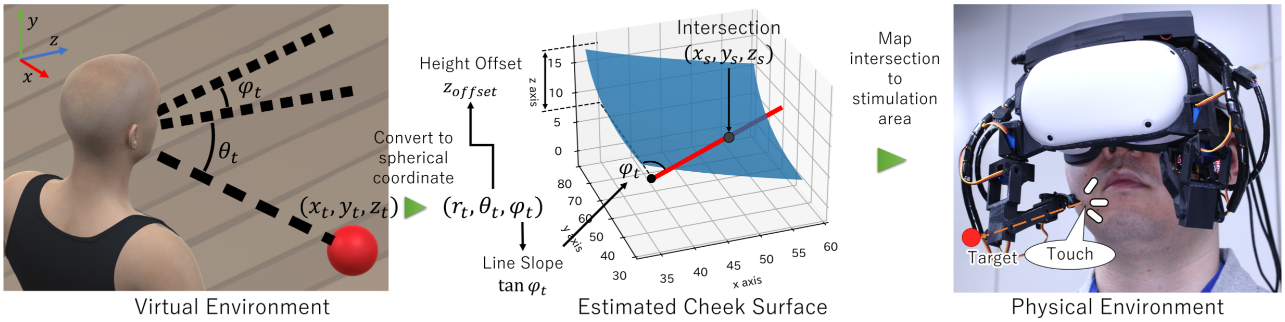

Figure 2: Target Directional Cue Presentation. A target position (x_t, y_t, z_t) was converted to azimuthal and elevational angles (θ_t, φ_t). The azimuthal and elevational angles were translated into a line. The azimuthal angle φ_t was used as a slope of the line, and the elevational one θ_t was transformed into a height offset. Our system calculated the intersection (x_s, y_s, z_s) between the estimated cheek surface and the line and mapped it to a stimulation area. The robot arm touched the mapped point.

sensors are attached to the bottom of an HMD to realize automated mapping between the robot arm coordinate and the cheek coordinate. We translate a target position into a cheek haptic stimulation for providing target directional information. We demonstrate two applications. In one application, sitting users search a target with haptic cues on a cheek. In the other application, standing users touch approaching targets relying on cheek haptics.

2 SYSTEM CONFIGURATION

We implemented an HMD-based system to present spatial directional cues on a cheek (Fig. 2). We built a haptic stimulation device by modifying an Oculus Quest 2. We attached two robotic arms to the left and right sides of the bottom of the HMD to stimulate the cheeks. The robotic arm consisted of five servo motors (three Tower Pro MG92B servos and two PowerHD DSM44 servos). The arm tips had four photo reflectors to detect a cheek surface. We mounted a circuit on the HMD to send photo reflector values and receive servo angles. The total weight of the two robotic arms (82g×2=164g) and the circuit (165g) was 329g. As a hardware limitation, our robotic arms generate small mechanical noises during stimulation.

In advance of cheek haptic stimulation, we estimated the cheek surface. The robot arms traced the cheek by detecting points on the cheek surface with photo reflectors. Photo reflectors measured the distance between the sensors and the cheek surface. Based on the distance, the robot arms went along the surface and then collected the points on the cheek surface. We fitted a quadratic surface to the points to estimate the cheek surface.

To stimulate the cheek, we encoded a target spatial information into a position on a cheek surface. At first, we transformed a target position into azimuthal and elevational angles by converting the Cartesian coordinate system to a spherical coordinate system. We translated the azimuthal and elevational angles into a line; the azimuthal one was used as the line slope; the elevational one was transformed into a height offset. We calculated the intersection between the estimated cheek surface and the line represented the target direction. The intersection was mapped to a stimulation area, and the robot arms touched the mapped position with a weak force (around 0.4N) to present the target directional cues. There was a latency of about 140 ms from the control signal generated in the virtual environment to robotic arm actuation.

3 DEMONSTRATION

To demonstrate our spatial directional guidance technique, we implemented two applications. Before the demonstration, we estimate the cheek surface by tracking the user's cheek surface.

(1) Users find a target image among 50 icons with the help of cheek haptics. The users were shown a target image for five seconds. Then, 50 icons appear in front of the users. The users look for the target relying on the cheek stimulation. This application lets the users perceive the directional information while sitting and concentrating on the cheek stimulation.
(2) Users touch approaching targets relying on cheek haptic stimulation. A target appears and approaches the users. The users search the target with the cheek stimulation and touch it. Through this application, the users intuitively understand the target direction while standing and moving actively.

4 CONCLUSION

We proposed Virtual Whiskers, a spatial directional guidance technique that presented haptic cues on a cheek. We attached two robot arms to the bottom of the left and right sides of an HMD to stimulate both sides of the cheeks. We estimated a cheek surface by tracing a cheek with the robot arms as a quadratic surface. In stimulating, we encoded the target's azimuthal and elevational angles into a point on the cheek and touched it with robot arms to present the target's directional cues. In the first demonstration, our system provided haptic stimulation encoded to a target image direction to help users choose the correct image. In the second demonstration, users touched the target with the help of the haptic cues.

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