Real-Time Bidirectional Head Rotation Sharing for Collaborative Interaction Enhancement

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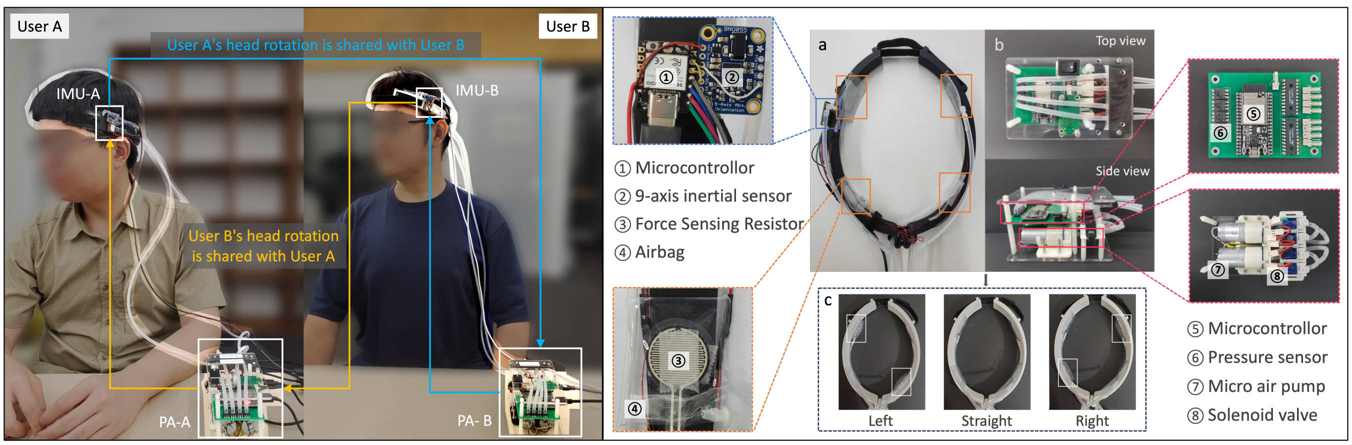

Figure 1: (Left) The system of bi-directional head rotation sharing. Measuring the rotation of users' heads through the inertial sensor (IMU), and using a pneumatic actuator (PA) to induce users' head movement. (Right) Hardware apparatus for the proposed system. a) Head frame; b) Pneumatic actuator; c) Rotation pattern.

ABSTRACT

Remote collaboration is becoming more prevalent, yet it often struggles with effectively conveying the spatial orientation of a remote participant. We introduce an innovative communication method that enables users to share their head direction. While traditional methods like written text and spoken language suit most situations, new approaches are necessary for scenarios lacking sufficient visual or auditory cues. For instance, how can hearing-impaired individuals share directional information during a remote collaborative game? This research presents an interactive system that induces head rotation based on the other user's head direction, allowing users to grasp each other's intended direction intuitively. This system improves communication by offering an additional means to share directional cues, especially in settings where visual and auditory cues are inadequate.

CCS CONCEPTS

• **Human-centered computing → Collaborative and social computing devices**.

KEYWORDS

Remote Collaboration, Hanger Reflex, Synchronous Rotation, Body Sharing

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1 INTRODUCTION

In daily life, the direction in which our heads are oriented typically indicates our direction of movement or our viewpoint. Communicating the head's orientation through non-visual and non-auditory means during remote collaboration can greatly improve remote communication methods. *HapticPointer* [3] employs 16 tactile actuators mounted on the neck to convey the orientation of a 3D target to the user. Using haptic feedback to provide remote users with directional cues enables navigation without relying on visual or auditory channels. However, vibrations can only offer suggestions to the user and cannot directly prompt actions, potentially increasing cognitive load during remote collaboration. Previous studies have explored sharing body movements that can directly prompt other user's actions. For instance, Nishida et al. have reported on a wearable device that can transmit kinetic sensations between two individuals [5]. *Electrical Head Actuation* [6] can also directly control the user's head orientation. Both *bioSync* [5] and *Electrical Head Actuation* [6] use electrical muscle stimulation (EMS) to induce muscle contractions and facilitate limb or head movement.

Nevertheless, because EMS involves placing electrodes on the skin and employing electric currents to trigger muscle contractions, it can lead to considerable discomfort and is unsuitable for individuals with metallic implants. Conversely, the Hanger Reflex technique can more comfortably induce head rotation. Kon et al. [1] documented a study that achieved head rotation using a pneumatic actuator, and *RemoconHanger* [2] demonstrated a one-way communication system to transmit head rotation to a remote person using the Hanger Reflex.

This research introduces an interactive system that allows users to subconsciously perceive the head rotation of a distant user, facilitating two-way communication between them (Figure 1(Left)).

2 SYSTEM DESIGN

To allow remote users to feel rotational movement, we have created a system depicted in Figure 1(Left). The data transmission process is as follows: 1) the rotation of user A's head is measured using an inertial sensor (IMU-A); 2) the rotation data is sent to the port of user B's pneumatic actuator (PA-B); 3) the pneumatic actuator (PA-B) is activated based on the rotation data and applies air pressure around user B's head; 4) user B's head rotates in the same direction as user A's. Similarly, when user B rotates their head, user A can be induced to rotate their head in the same direction.

Apparatus: Figure 1 (Right) illustrates one of the devices for the proposed system, which necessitates two identical sets of devices. The device is composed of two primary components: a head-mounted frame (a) and a pneumatic actuator that can be placed on a table (b). The head frame is equipped with a 9-axis inertial sensor (Adafruit BNO055 Absolute Orientation Sensor, BOSCH) to measure the yaw axis rotation angle, four airbags (W:50mm, H:40mm) to apply pressure to the forehead and back of the head, and four Force Sensing Resistors (FSR, MD30-60 model, D:30mm, Simlug) positioned between the airbags and the frame for pressure calibration. The inertial sensor and Force Sensing Resistors are managed by a microcontroller (XIAO ESP32C3, Seeed Studio).

Figure 1(Right(b)) shows the components of the pneumatic actuator. The hardware construction for this actuator is based on the design of *HangerBody* [4], which we have replicated and subsequently modified to suit the requirements of our proposed interaction system.

Communication Mode: In the *RemoconHanger* [2], the sender utilized a rotation measurement device, while the receiver employed a hanger reflex device for unidirectional communication. In contrast, we introduce a bi-directional communication system that enables two users to control each other's head movements reciprocally. Drawing inspiration from walkie-talkies and telephones, we devised two modes of bi-directional communication: half-duplex communication (HDX) and full-duplex communication (FDX).

The half-duplex system supports communication in both directions, but only one direction at a time, not concurrently. Participants can switch roles between sender and receiver by pressing a button. The full-duplex system, unlike the half-duplex, allows simultaneous communication in both directions. Moreover, since the receiver obtains data through induced rotation, and this passively induced rotation is also detected by the inertial sensor and sent back to the original data sender, it leads to communication confusion. To address this, we employed the FSR to distinguish between active and passive rotations, as passive rotations occur under pressure applied by the airbags. This ensures that only data from active rotations is transmitted to the other user, while data from passive rotations is not transmitted.

3 DEMONSTRATION

To showcase the capabilities of this system, we will have two participants wear the head frames shown in Figure 1(Left). As detailed in the system design section, each participant can send rotation data and is prompted to rotate upon receiving data. Although our design supports remote data transmission via WiFi, due to the dense crowds at the exhibition, we will set up the system to transmit data through different USB ports. The two participants in the demonstration will feel the sensation of directly controlling the head rotation of the other person, as well as being controlled by the other person. Additionally, as a safety measure, we set a maximum air pressure for each airbag to ensure that there is no risk of injury to users during the head movement induction process.

4 POTENTIAL APPLICATION

The proposed bi-directional head movement control system offers numerous promising applications across various sectors. In the context of virtual reality (VR) and augmented reality (AR), this system can greatly improve remote collaboration and gaming experiences by enabling users to naturally share their perspectives and directional intentions without depending solely on visual or auditory signals. This feature is especially advantageous for individuals with hearing impairments, as it provides an effortless method to convey directional information during cooperative tasks or immersive gameplay. In summary, the capability to share head movements introduces new opportunities for enhancing communication, collaboration, and training in multiple fields, making it a valuable enhancement to current interactive systems.

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