Demonstration of Electrical Head Actuation: Enabling Interactive Systems to Directly Manipulate Head Orientation

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ABSTRACT

We demonstrate a novel interface concept in which interactive systems directly manipulate the user's head orientation. We implement this using electrical-muscle-stimulation (EMS) of the neck muscles, which turns the head around its yaw (left/right) and pitch (up/down) axis. At SIGGRAPH 2022 Emerging Techinologies, we will demonstrate how this technology enables novel interactions via two example applications: (1) finding different visual targets in mixed reality while the system actuates the user's head orientation to guide their point-of-view; (2) a VR roller coaster application where the user's head nods up as the ride accelerates.

ACM Reference Format:

Yudai Tanaka, Jun Nishida, and Pedro Lopes. 2022. Demonstration of Electrical Head Actuation: Enabling Interactive Systems to Directly Manipulate Head Orientation. In *Special Interest Group on Computer Graphics and Interactive Techniques Conference Emerging Technologies (SIGGRAPH '22 Emerging Technologies), August 07-11, 2022.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3532721.3535567

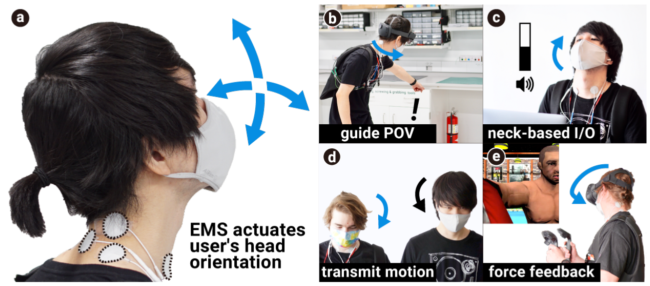

Figure 1: (a) Our novel interface concept that enables interactive systems to directly actuate the user's head orientation around its yaw and pitch axis via electrical muscle stimulation. It opens up a range of applications: (b) directly changing the user's point-of-view to locate objects (e.g., a fire extinguisher); (c) a sound controller that uses neck movements as both input and output; (d) transmitting one's neck movement to another; (e) rendering force feedback from VR punches.

1 INTRODUCTION

While head movements are integral in life and, in many interactive systems (e.g., scanning one's surroundings in VR/AR or as nonverbal cues in telepresence), researchers have rarely explored ways to directly utilize head movements as output.

There have been four types of explorations in actuating the head: (1) emergent exoskeletons used only in medical rehabilitation [Zhang et al. 2019]; (2) mounting a flywheel to the VR headset to render inertial forces, which uses the gyroscopic effect as the user's head is actively moving [Gugenheimer et al. 2016]; (3) mechanically applying pressure to the head causing it to jerk in one direction, denoted as hanger reflex [Kon et al. 2017]; and (4) using air jets mounted to the VR headset to render accelerations of the head [Liu et al. 2020]. Unfortunately, while all the above haptic interfaces are promising, they are built around the assumption that one can just attach actuators to a headset or, even more dramatically, that users will be excited to attach actuators on their face, forehead, etc. Thus, these are mostly limited to VR, where a headset is already present.

Instead, in this paper, we demonstrate a novel approach that empowers interactive systems with direct control of the user's head orientation by actuating the user's neck muscles with electrical muscle stimulation (EMS). Our system is depicted in Figure 1 (a). The fact that it builds on EMS results in a haptic device capable of actuating the user's head without requiring any attachments on the user's face/head or above the neck muscles—e.g., a simple turtleneck would cover our system's EMS electrodes entirely. This opens up a variety of applications (Figure 1 b-e): (1) directly changing the user's head orientation to locate objects; (2) a sound controller that uses neck movements as both input and output; (3) communicating head movements between two users, which enables a user to communicate head nods to another user while listening to music; and (4) rendering force feedback from VR punches on the head. The details regarding these applications as well as the electrode placements, safety measures, implementation, and the control accuracy of our system can be found in [Tanaka et al. 2022].

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SIGGRAPH '22 Emerging Technologies , August 07-11, 2022, Vancouver, BC, Canada
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ACM ISBN 978-1-4503-9363-8/22/08.
https://doi.org/10.1145/3532721.3535567

2 IMPLEMENTATION

2.1 Hardware

Figure 2 depicts our wearable hardware setup that ensures a user's mobility. The system stimulates the user's neck muscles at 30 Hz using a medical-grade electrical muscle stimulator (HASOMED RehaMove3) which the user carries in a slim backpack. Our system utilizes four channels of the EMS stimulator to actuate the head accordingly to the electrode placement found in our preliminary exploration: (1) turn left by stimulating the left side of the splenius capitis; (2) turn right by stimulating the right side of the splenius capitis; (3) nod up by stimulating the splenius cervicis; and (4) nod down by stimulating the sternocleidomastoid. For tracking head orientation, we made our system compatible with HoloLens 2, HTC VIVE, and AirPods Pro earbuds, such that the user equips one of them based on the application type (i.e., MR, VR, and real environment). The interface between the EMS stimulator and the tracking device(s) is a laptop (MSI GL65 Leopard) running our Unity3D applications; the laptop is also stored in the user's backpack.

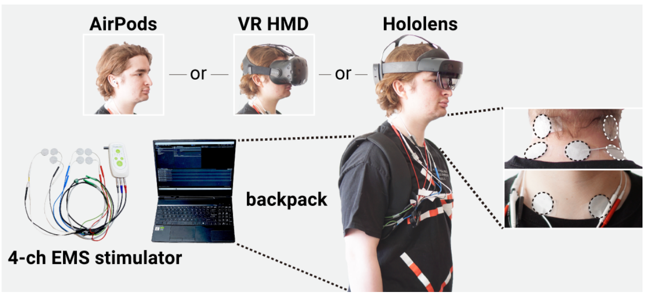

Figure 2: Our wearable system setup.

2.2 EMS Control Loop

To actuate the user's head to a target orientation, we implemented a PID controller, designed specifically for neck EMS. The PID controller regulates the pulse-width of the EMS impulses between the range of 0 us and 300 us. In each cycle, the system calculates the error (e_x, e_y) between the user's head orientation, given by the current orientation (obtained from tracking), and the target orientation. Note that the x axis here represents head rotations around the yaw axis (i.e., turn left/right) and the y axis represents head rotations around the pitch axis (i.e., nod up/down). With the input of e_x and e_y, our PID controller individually computes PW_x and PW_y, which are final EMS pulse-widths for actuating the user's neck to turn horizontally and/or nod vertically towards the target respectively. Our controller is dual in that, if PW_x is positive, it will be set as the pulse-width for the right-channel; if PW_x is negative, it will be negated and set as the pulse-width for the left-channel; similarly, if PW_y is positive, it will be set as the pulse-width for the up-channel, and vice-versa for the down-channel. For instance, in one cycle, $(PW_x, PW_y) = (-100, 200)$ dictates that left-channel outputs a 100 us pulse and up-channel outputs a 200 us pulse. Via initial pilots, we settled on the following PID coefficients $(K_p, K_i, K_d) : (16, 4, 2)$. Note that our PID controller works without any voluntary movement by users; if the neck's own springiness or the user moves away from the target, the PID will push it back without user intervention.

3 USER EXPERIENCE

At SIGGRAPH 2022 Emerging Technologies, we will demonstrate the proposed electrical head actuation. First, attendees can observe the system in action being worn by the author. Attendees are given a joystick gamepad and can control the neck of the author via EMS, live and in front of them. Now, the author asks the attendee if they would like to be controlled. If yes, they will proceed with a safe EMS calibration. After that, they try the guiding point-of-view applications (Figure 3) where the author controls the attendee's head orientation with EMS to acquire different visual targets shown on the Hololens display. Considering the limited time for demonstration, if necessary, the attendee can instead experience an application that only requires one EMS channel, which substantially shortens calibration time. In this case, they experience a VR roller coaster application where their head nods up as the ride accelerates.

Figure 3: An example of guiding the user's point-of-view using our system. (a) The user sees a fire in mixed reality (MR) fire safety training but, (b) cannot locate the fire extinguisher. (c) Our device actuates their head to look at it.

4 CONCLUSIONS

We demonstrated a novel interface concept in which the interactive system actuates the user's head orientation. We implemented this concept by applying electrical muscle stimulation (EMS) to the user's neck muscles, enabling our system to actuate the user's head orientation around its yaw and pitch axis. We believe our work will inspire researchers to further delve into this avenue of directly controlling the user's head orientation.

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