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Collaborative VR Attraction Enhancing Player Abilities Through Audience Electromyography Signals

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Abstract

In this study, we propose an innovative method that allows game players and audiences to interact collaboratively using electromyography (EMG) signals as a user interface (UI). We also develop a VR attraction, "Element Magic Genesis," as an application of this method. In this application, two users participate, with one as a player and the other as the audience. The player's abilities are enhanced based on the intensity of the audience's EMG signals. This attraction allows them to have a more immersive and unitary sense while interacting in a VR environment.

CCS Concepts
• ***Human-centered computing*** → *Virtual reality, Collaborative interaction ;*

1. Introduction

In this study, we propose an innovative interaction method in which game players and audiences collaborate by unitizing audience electromyography (EMG) signals as a user interface (UI). We demonstrate the application of this method through a VR attraction, "Element Magic Genesis," in which the audience can enhance the player through their support. Many people have experienced straining their bodies while watching an exciting game, even as audiences. The audience would be able to support the players intuitively and directly by utilizing their EMG signals as a UI, without distracting their focus on the game. EMG signals are used as input for various systems, including applications such as robotic prosthetic arms and electric wheelchairs [YNH*12] [SG82].

Previous studies have proposed methods to promote collaboration between the players and audiences. Kawamoto [KKK19] has suggested participative support devices that light up in response to audiences' voices. However, this system is not suitable for situations when noise critically affects the game, such as blind soccer. Minagawa [MN18] developed a system for blind soccer in which audiences express support by shaking their arms. While they address the issues related to noise, this system requires the sufficient distance between audiences to move their body safely. EMG devices can be implemented in limited space and does not make any operational noise. Furthermore, no study has investigated the collaboration between players and audiences using force control based on the EMG signals.

Figure 1: *Overview of the "Element Magic Genesis" experience. The player controls a VR avatar, and the audience supports them with EMG signals from their arms.*

2. Application: "Element Magic Genesis"

2.1. Overview

"Element Magic Genesis" is a VR attraction that we developed as an application of the EMG support system (Figure 1). In this attraction, two users participate, with one as a player and the other as the audience, and battle the enemy. The player controls a VR avatar that is responsible for attacking the enemy and defending against enemy attacks in a VR environment. The audience enhances the strength of the player's attack and generates appropriate defensive shields based on the intensity of the force applied to their arms. To promote the interaction between the player and the audience, we incorporate the element of collaboration between them. This attraction is conducted in two phases, as described below.

Attack phase: The player attacks the enemy by punching with both hands. The power varies depending on the audience's EMG.

Defense phase: The player defends against two-colored attacks from the enemy, holding a shield that matches the attack color. The color of the shield is switched according to the strength of the audience's EMG signals.

2.2. Support Mode

Using EMG signals as a UI, users can input their force at three different levels [HKSK22]. It has been shown that users control their forces more stably with weak strength when they strain continuously [NKAC*23]. In this study, we adopt two types of input methods as support modes according to the audience's strain: threshold and continuous. The input threshold for each audience is decided via calibration. Details of the two modes are described below.

Threshold mode: The attack power is amplified when the audience's EMG exceeds the threshold when the player initiates an attack. The audience controls the moment of straining by observing the player's action. The attack is intense when the player attacks within 1.5 seconds after the audience's EMG exceeds the threshold. The input threshold for EMG is designated at 50%.

Continuous mode: The audience switches between the red and blue shields by continuously straining with a designated level of force with their arms. When EMG is between 20% and 49%, a blue shield appears along the extension of the player's left controller, and when it exceeds 50%, a red shield is generated along the extension of the player's right controller. To prevent a blue shield from appearing when no force is applied to the arms, we set the minimum threshold at 20%.

We display a force magnitude gauge within the player's and audience's viewing areas, allowing them to monitor the audience's strain level (Figure 2). The color of the gauge changes gradually based on the audience's EMG signals; it turns red when the input is 100% (maximum straining) and green when the input is 0% (not straining).

2.3. System Configuration

Figure 3 shows the system configuration of the attraction. The player wears a video see-through Head-mounted display (Meta Quest 3) on their head and holds controllers in both hands. The position of the controllers is tracked, and an attack is launched in the direction of the controller's ray when it is 1.5 m away from their face (attack phase). The audience wears two EMG electrodes on their dominant arm and experiences the attraction by observing the player with a wider viewing area. Unity (2023.2.8f1) receives sensor data and renders virtual objects. The system runs at approximately 120 fps.

The amplitude of the EMG device ranges from -1.25 mV to 1.25 mV. The surface EMG signals are amplified 1000 times, and A/D conversion is applied to them. The sampling frequency is 1kHz, and the EMG signals are transmitted to the computer. EMG signals is filtered, and a range of 5-500 Hz frequency is utilized (except 55-66 Hz to avoid power supply noise). We perform signal smoothing using the root mean square (RMS). We set the RMS window to 300 ms with a sliding window of 10 ms.

Figure 2: *The force magnitude gauge*

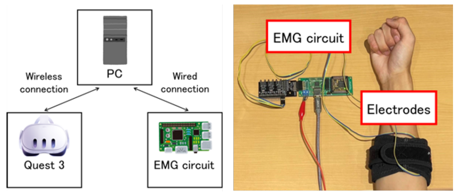

Figure 3: *System configuration and EMG device*

3. Experience

In this demonstration, a player and an audience experience attack and defense phases. In the attack phase, the player attacks a virtual enemy, and the audience supports them through a threshold mode. In the defense phase, the player defends themself from an attack from an enemy, and the audience supports them through a continuous mode.

In preliminary demonstrations, participants who played the audience role reported that the immersion into the attraction is enhanced when they expressed support by straining their arms. We observed that the player and the audience were more united. This demonstration contributes to the investigation of collaborative interaction between people using different input sources in VR environments.

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